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BEFORE THE TRADEMARK TRIAL AND APPEAL BOARD

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TITLE: Capitalizing on early project decision-making opportunities to improve facility design, construction, and life-cycle performance--POP, PM4D, and decision dashboard approaches

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BODY:

ABSTRACT

In this paper, we assess the requirements of architecture, engineering, construction (AEC) decision making and explain the limitations of state-of-the-art practice and theory in supporting informative formulation, clear and flexible evaluation, and quick re-formulation of AEC alternatives. We introduce the concept of Virtual Design and Construction (VDC) through results from several case studies that utilized Product, Organization, and Process (POP) Modeling and the Product Model and the Fourth Dimensional (PM4D) approaches in supporting design, construction, and life-cycle performance decisions. While VDC applications contribute to more accurate, informative, and efficient formulation of AEC alternatives, we discuss the needs for research on a Decision Dashboard to formally represent, organize, and decouple various decision contents (i.e., options, alternatives, predictions, and criteria) to support better evaluation and re-formulation of AEC alternatives.

FULL TEXT

1 Introduction

In the field of architecture, engineering, and construction (AEC), professional consultants guide their clients in making decisions that have both strategic and tactical implications for the quality, cost, duration, and resource allocation of a project alternative. Once a decision need or a challenge arises, AEC consultants apply their professional skills to formulate different option plans. They predict and evaluate the performance of such option plans. Based on their client's decision criteria such as budget, risk attitude, specifications, and milestones, the consultants combine option plans to formulate and recommend project alternatives to their clients for selection. Such decision-making scenarios take place in many phases of a design and construction project. In pre-project planning, developers compare financial prospects of different property sites for investment decisions; in schematic design, building owners compare aesthetics, cost, and the life-cycle performance of different design proposals for development decisions; whereas in construction engineering and management, the developers and their contractors compare different acceleration proposals to mitigate unforeseen delays during construction.

At the Center for Integrated Facility Engineering (CIFE) in Stanford University, we follow a research approach that strives to balance practical and theoretical advancements. One of CIFE's missions is to promote and extend the use of VDC technologies to support the visualization, analysis, and evaluation of the multidisciplinary performance of facility projects in support of AEC decisions [1]. This paper captures our collaboration experience with various industry partners on the following projects:

- design, construction, and life-cycle analyses of a university auditorium project, with a capacity of 600 seats and a construction cost of about $5US million,
- design coordination and construction of a biotechnology laboratory project, with an area of over 25,500 m^2 and a design and construction budget of over $130US million,
- acceleration proposals for a retail complex project during construction, with a construction budget of over $72US million,
- pre-construction planning on a museum project, with an estimated $300US million design and construction cost, and
- pre-construction planning on a hospital project, on a 55,000 m^2 site.

Based on our observations and industry involvement in these cases, we explain why current practice does not support informative formulation--one of three requirements--of decision alternatives. We then present Product, Organization, and Process (POP) modeling as well as the Product Model and the 4th Dimension (PM4D) as examples of VDC approaches and discuss their benefits on the design, construction, and life-cycle performance of the aforementioned industry cases. In spite of the visual and analytical benefits of VDC technologies, we then illustrate the need to support the evaluation and re-formulation of AEC alternatives with formal handling of various decision contents. We motivate the need of our ongoing research, which focuses on the representation and organization of heterogeneous decision contents to support a more informative, flexible, and repeatable selection of AEC alternatives.

2 AEC decision making

Decision is an irrevocable allocation of resources [2]. Information, preference, and choice are the three parts of "Decision Basis", which synthesizes the decision problem and allows for logical evaluation, analysis, and appraisal of the recommended decision alternatives [3]. Theory in AEC decision making establishes requirements that align with the decision basis. Value engineering theories [4,5], set-based design [6], the "Level of Influence" concept [7], and industrial case studies [8] rationalize the benefits of gathering an extensive and balanced information basis, setting up public and explicit criteria, and generating multiple alternatives in early project phases. In summary, coming up with a good decision in AEC requires informative formulation, clear evaluation, and quick re-formulation.

2.1 Informative formulation

The quality of decision making depends on its information basis. Parameters such as performance level, cost, activity duration, and resource needs may separately or collectively influence the selection of AEC alternatives. Therefore, the more extensive and balanced the inputs of information (i.e., options, alternatives, predictions, and criteria, which we call collectively decision contents), the more informed the decision basis becomes.

Prior to the employment of VDC tools on some of our case studies, we observed that practitioners lack the resources to effectively generate and communicate decision factors. In the biotechnology project, the Director of Research suddenly came up with an idea of swapping the laboratory spaces with the office spaces late during the design process. The architects and owner representatives foresaw potential ripple consequences that this decision would have for other consultants and their work in place. In spite of the verbal explanations and the skepticism expressed by the team, the Director did not find any solid compelling evidence against his strongly held idea of changing the spatial configuration. As Section 3.1.1 explains, VDC technologies allow non-AEC professionals to visually comprehend the physical product of the design while integrating components and systems from different specialty designers.

In the hospital project, construction planners communicated their construction sequencing plans with a binder of 60 color-labeled plans. Each color plan denoted a specific construction activity and referenced to another sheet of schedule information. This manual, custom, and hence non-repeatable, process required significant time commitment for planners to generate each alternative and for reviewers to comprehend the binder. In Section 3.1.2, we discuss how VDC technologies expedite this process by promoting a more repeatable modeling approach while promoting a more easily understandable means to review the construction sequences.

In the museum project, the pre-construction consultants were contemplating two structural systems--structural steel and reinforced concrete--to support the roof garden. The project director for the contractor intuitively understood the organizational advantages of self-performing the concrete roof system over subcontracting the structural steel work. However, the project director lacked evidence to support his argument. In Section 3.1.3, we explain how VDC technologies provide simulation results that assess the impact of different ways to organize the design and construction of projects on project performance.

In the university auditorium project, the clients were to decide upon two air-conditioning systems--mixed cooling versus displacement (or underground) cooling. Had the project team not conducted VDC analyses to study the life-cycle performance of mixed versus displacement cooling systems, the cost-sensitive decision makers would have probably selected the mixed system rather than the displacement cooling system. In Section 3.3, we detail the background, process, examples, and results of the VDC approach to illustrate how the approach contributed to the formulation of alternative proposals for the clients to make an informed decision early in the project.

In a nutshell, VDC technologies are valuable in automating and supporting informative formulation of AEC alternatives.

2.2 Clear and flexible evaluation

Given various options and alternatives, the evaluation is dependent on the means of providing decision makers with pertinent decision contents. An evaluation has to be clear such that all involved stakeholders can understand how the predicted performance of the alternatives fares against the decision criteria. An evaluation also has to be flexible such that the stakeholders can shift their decision foci (among macro- and micro-decision issues) and make necessary queries according to the issues at stake.

In the retail complex project, unforeseen soil contaminants had delayed the construction project critically for 2 months. The developers had to evaluate different acceleration alternatives and balance the conflicting interests of on-time turnover, low change order cost, and project risks. As with other aforementioned cases, we applied VDC technologies to simulate the integrated challenges of the physical product design, organization team dynamics, and process sequence of the project. In addition, we utilized the interactive workspace feature of VDC to support the description and evaluation of various project alternatives (see Section 3.2). However, in spite of these VDC approaches, Section 4 explains the limitation of existing theories and methods to provide clear and flexible evaluation decision supports. We explain the research needs and anticipated implications of developing a Decision Dashboard--a visual interactive tool for the synthesis of decision options, alternatives, predictions, and criteria.

2.3 Quick re-formulation

The time and the process it takes to re-formulate new alternatives determine the number of alternatives tested by the project stakeholders. We hypothesize that the quicker and the simpler the re-formulation process, the more alternatives the decision makers can create, and the better value the decision-making process generates.

Although the end-users of the aforementioned university auditorium project provided valuable functional inputs to the designers during a schematic review meeting that took place in an immersive virtual reality environment, the amount of model and data customization in preparation of similar interactive meetings limited the number of additional alternatives the project team could re-formulate in a timely manner [8]. Similarly in Section 4, we explain the difficulty to decouple alternatives to re-formulate them on examples from the aforementioned retail complex project. We also explain how our ongoing research in developing a Decision Dashboard may address this limitation.

3 Virtual design and construction

--to support the roof garden. The project director for the contractor intuitively understood the organizational advantages of self-performing the concrete roof system over subcontracting the structural steel work. However, the project director lacked evidence to support his argument. In Section 3.1.3, we explain how VDC technologies provide simulation results that assess the impact of different ways to organize the design and construction of projects on project performance.In the university auditorium project, the clients were to decide upon two air-conditioning systems--mixed cooling versus displacement (or underground) cooling. Had the project team not conducted VDC analyses to study the life-cycle performance of mixed versus displacement cooling systems, the cost-sensitive decision makers would have probably selected the mixed system rather than the displacement cooling system. In Section 3.3, we detail the background, process, examples, and results of the VDC approach to illustrate how the approach contributed to the formulation of alternative proposals for the clients to make an informed decision early in the project.In a nutshell, VDC technologies are valuable in automating and supporting informative formulation of AEC alternatives.2.2 Clear and flexible evaluationGiven various options and alternatives, the evaluation is dependent on the means of providing decision makers with pertinent decision contents. An evaluation has to be clear such that all involved stakeholders can understand how the predicted performance of the alternatives fares against the decision criteria. An evaluation also has to be flexible such that the stakeholders can shift their decision foci (among macro- and micro-decision issues) and make necessary queries according to the issues at stake.In the retail complex project, unforeseen soil contaminants had delayed the construction project critically for 2 months. The developers had to evaluate different acceleration alternatives and balance the conflicting interests of on-time turnover, low change order cost, and project risks. As with other aforementioned cases, we applied VDC technologies to simulate the integrated challenges of the physical product design, organization team dynamics, and process sequence of the project. In addition, we utilized the interactive workspace feature of VDC to support the description and evaluation of various project alternatives (see Section 3.2). However, in spite of these VDC approaches, Section 4 explains the limitation of existing theories and methods to provide clear and flexible evaluation decision supports. We explain the research needs and anticipated implications of developing a Decision Dashboard--a visual interactive tool for the synthesis of decision options, alternatives, predictions, and criteria.2.3 Quick re-formulationThe time and the process it takes to re-formulate new alternatives determine the number of alternatives tested by the project stakeholders. We hypothesize that the quicker and the simpler the re-formulation process, the more alternatives the decision makers can create, and the better value the decision-making process generates.Although the end-users of the aforementioned university auditorium project provided valuable functional inputs to the designers during a schematic review meeting that took place in an immersive virtual reality environment, the amount of model and data customization in preparation of similar interactive meetings limited the number of additional alternatives the project team could re-formulate in a timely manner [8]. Similarly in Section 4, we explain the difficulty to decouple alternatives to re-formulate them on examples from the aforementioned retail complex project. We also explain how our ongoing research in developing a Decision Dashboard may address this limitation.3 Virtual design and constructionOne of the major benefits of Virtual Design and Construction (VDC) simulation and modeling is the ability to quickly identify different options, quantitatively predict options' behaviors, evaluate the alternatives, and assess the project alternatives before committing to a major decision. The following sections explain the Product, Organization, and Process (POP) modeling approach; interactive workspace (iRoom), which is capable of cross-referencing POP models and information across different computers and displays; and the Product Model and the 4th Dimensional (PM4D) approach, which we developed and tested in an international pilot project.

3.1 POP modeling approach and implications on design and construction decisions

POP models complement 3D product models with process and organization models for a more comprehensive method for virtual design and construction. Based on our collaboration experience with industry partners, we conclude that the POP modeling approach supports better coordination, visualization, and planning than conventional practice. We explain these conclusions with examples in the following sections.

3.1.1 Product modeling

Product modeling tools such as Autodesk Architectural Desktop or Graphisoft ArchiCAD virtually model the physical components or features of a design (Fig. 1) and allow engineers to leverage the 3D object intelligence for tasks such as quantity takeoff and thermal analyses. At the same time, the explicit three-dimensional information of product models facilitates spatial coordination and construction planning among different AEC specialty professionals.

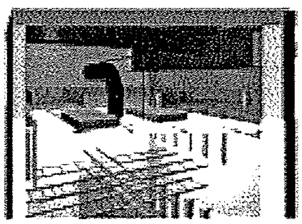

Fig. 1. Graphical view of a product model showing components of architectural walls, structural beams, mechanical ducts, electrical cable trays and conduits, and fire sprinklers (3D model built with Architectural Desktop Version 3.3).

Subsequent to the change requested by the Director of Research in the biotechnology case study, we collaborated with the project teams to construct a three-dimensional product model of the laboratory facility. During the modeling process, the team was able to identify several spatial conflicts between architectural, structural, and building systems components that had not been identified in the two-dimensional drawings. Furthermore, the product models provided the clients with a vivid representation of the complexity and value of prior architectural, structural, mechanical, electrical, and plumbing coordination in place. The models helped the project team members to explain the ripple effects of a seemingly minor spatial reconfiguration to the clients.

3.1.2 Product-process modeling

4D modeling is an example of product-process modeling, which integrates a 3D product model with a schedule. By animating a 3D product model based on the linkages to a construction schedule, a 4D model communicates the sequence of planned work visually and helps planners identify schedule conflicts, safety hazards, and acceleration opportunities.

In the hospital case, a student team spent approximately 10 person-hours to construct a high-level product model of the hospital components in 3D; 2 person-hours to develop a process model based on the sequencing information we gathered from the professionals; and 1 person-hour establishing the product-process linkages (Fig. 2). Instead of reading through a 60-page binder, reviewers could comprehend the construction schedule more quickly with the 4D model. Furthermore, the student team was able to leverage the product model and the process model for developing alternative sequence plans. Rather than manually generating a whole new binder for an alternative schedule, it took 2 additional person-hours to develop a schedule alternative with the VDC approach.

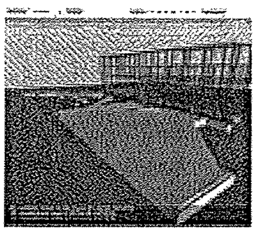

Fig. 2. Snapshot of a 4D model highlighting specific construction activities scheduled for a particular day in the construction sequence of the hospital project (4D model created with Common Point 4D).

3.1.3 Organization-process modeling

We use ePM SimVision to model and simulate the interaction among teams, organizations, and their associated responsibilities throughout different phases of a project. Such organization-process modeling allows users to predict coordination bottlenecks, team backlogs, and hidden work under different staffing and teaming plans.

For the museum project, a student team interviewed various project team members, gathered relevant information, and modeled the work processes along with the hierarchy and staffing of the project teams in ePM SimVision (Fig. 3). The simulation provided qualitative and quantitative evidence, such as schedule risk, position backlogs, and communication risk, with which the project director could assess the two design and construction alternatives.

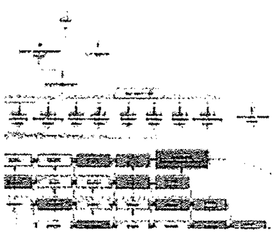

Fig. 3. A partial view of the SimVision organization-process model from the museum project.

3.2 The interactive workspace

Johanson et al. [9] define the Interactive Workspace (iRoom) as interfaces and an infrastructure that are characterized by heterogeneity, multiplicities, and dynamism among users, devices, and software applications. In collaboration with the Computer Science Department in Stanford University, CIFE has assembled an iRoom in its facility. The ongoing CIFE iRoom research aims at defining and evaluating new ways for project teams to interact with and visualize project information to facilitate fast and effective decision making in a group context [10]. On the aforementioned retail complex, museum, and hospital projects, we have tested with industry practitioners the real-time referencing capabilities that utilize common parameters such as dates and names to unify the focus of POP and related cost models (Fig. 4).

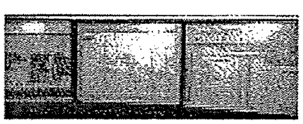

Fig. 4. A snapshot from the retail complex project in which the iRoom supported the cross-referencing of POP models and multidisciplinary views.

On the retail complex project, the iRoom infrastructure allowed us to evaluate different acceleration alternatives by touching on a particular milestone on the process-model displays which prompts, e.g., automatic responses by the adjacent product/process-model displays to show corresponding 4D views of schedule alternatives.

3.3 PM4D approach and implications on life-cycle performance

Collaborating with its Finnish partners, CIFE developed and tested the PM4D approach in the Helsinki University of Technology Auditorium-600 pilot project [8]. HUT-600 was the first live and large-scale industrial application of the Industry Foundation Classes (IFC) interoperability standard. We documented the life-cycle studies made during the early schematic design phase of HUT-600, explained how the PM4D approach supports the life-cycle studies, and analyze the anticipated implications of the PM4D approach and the life-cycle studies on the long-term performance of the capital facility [8]. Below, we summarize the insights from this project as they relate to the topic of this paper.

HUT-600 consultants noted, and conferred with the project construction managers, that in the total spending on a capital facility, 80% of the total cost is spent on the operation and maintenance, whereas the remaining 20% goes to planning, design, and construction. Hence, it is crucial to capitalize on early project opportunities to optimize the facility design for long-term performance.

The PM4D approach relies on product modeling and interoperability standard(s) to eliminate the inefficiency and risks of data re-entry in conventional practice. The approach aims at leveraging state-of-the-art analytical and visualization tools to optimize the design, construction, and operation of a proposed facility during early project phases. The approach recognizes the importance of having cross-disciplinary expertise to improve design and construction integration and performance. With the goal of improving the quality of design and construction services, the approach called for utilizing intelligent object-oriented product models and the IFC interoperability standard to support data sharing. Furthermore, the approach adopted various visualization tools and analysis tools for life-cycle performance studies for early-project decision making.

During the early schematic phase, the architects and mechanical engineers designed with object-oriented modeling software such as Graphisoft's ArchiCAD and Progman Oy's MagiCAD. The IFC release 1.5.1 interoperability standard reduced the needs to re-enter geometric data, thermal values, and material properties [8]. Efficient model and data sharing during the schematic design phase allowed the building-systems consultants to simulate various cooling and heating requirements based on the architectural product model. These thermal values were directly imported to the Heating, Ventilating, and Air-Conditioning (HVAC) design application, where the mechanical consultants laid out the distribution paths. The software then automatically sized and balanced the mechanical components. The object-oriented HVAC application then exported the geometry of ducts and air handling units for the architects to incorporate into the architectural model and generated a bill of materials for the general contractor.

Synthesizing the readily available bill of materials from the mechanical consultants and the three-dimensional geometry from the architects, the general contractor for HUT-600 utilized an automated cost estimating and value engineering system, again object-oriented and IFC-compliant, to match design components with the contractor's database for cost estimation, scheduling, and resource leveling.

Compared to a conventional approach, this relatively seamless data exchange and the related automated tools tremendously expedited design time and improved the quality of interdisciplinary collaboration [8]. As a result, the project team quickly generated three design and two building system alternatives and other work that directly added value to the clients' and users' ability to understand the project design and make necessary decisions in a timely and efficient manner.

Kam et al. also reported that in HUT-600 the use of object-oriented product models and the IFC interoperability standard resulted in about 50% time savings in design documentation for some disciplines, as a result of the object-oriented library, parametric properties, knowledge reuse, and data sharing. The PM4D approach expedited the traditional schematic design services while helping the engineering and construction professionals to develop more project alternatives to greater detail than is typically economically possible today. As a result, the project team shifted their attention from performing routine jobs to conducting life-cycle analyses. Such analyses added value to the project by reducing the risks of cost overrun or dissatisfaction of long-term performance.

By March 2001, only 3 months into the design phase, a rich set of analytical results were available to the owner and the project team members. Subsequently, the owner evaluated various project alternatives (e.g., architectural features, mixed versus displacement cooling systems, etc.) based on their functional performance, projected operating costs, maintenance costs, and environmental impacts and chose the designs and systems that best met their long-term strategic goals. In the selection of the air-conditioning system, the owners were confident to invest in the more energy efficient, environment-friendly, slightly more expensive, and better performance system--the displacement cooling system.

The HUT-600 project team also explored various visualization tools, such as virtual reality-EVE, 4D CAD, virtual animations, etc., to foster early and effective communication among the end-users, owner, and project team. In particular, the HUT-600's project team conducted a series of life-cycle analyses to evaluate the thermal performance, cost implications, and environmental impacts of project alternatives. In the following subsections, we explain how the project team evaluated two air-conditioning system alternatives--mixed cooling versus displacement cooling systems. In mixed cooling, the system supplies high velocity cold air from the ceiling. It is simpler in design and cheaper in cost when compared to a displacement cooling system, which slowly cools the space from the floor and displaces the warm air up to the exhaust in the ceiling.

3.3.1 Thermal performance

The mechanical engineers utilized Olof Granlund Oy's RIUSKA for thermal simulations and AEA Technology's CFX to conduct computational fluid dynamics (CFD) analyses. Since the auditorium space was a critical room with heat emission from 600 users and more than 200 light fixtures, RIUSKA's predictions and CFX's analyses enabled the engineers to quantitatively compare the profiles of temperature and air velocity stratification between the mixed and the displacement cooling schemes.

Based on 3D model input, RIUSKA accounts for the dynamic behavior of thermal masses in response to the changing exterior temperatures through an hourly increment over a 12-month period. Thus, engineers could combine different spaces and building systems to test various insulation and construction assembly options. Once the indoor air temperature target was specified, the program took a few minutes to analyze the thermal loads from the occupancy, the occupants' schedule, the equipment, and the exterior temperature conditions against the different insulation schemes, window transmittance, and louver systems.

Taking RIUSKA's analysis results as its target range and boundary conditions, CFX took about 10 h to iteratively solve for the finite numeric values of air temperature and supply air velocity across the sectional profiles of the auditorium space. The CFX results illustrated that in spite of a supply of lower air temperature of 17 °C, the mixed cooling system was not as efficient as the displacement cooling system (with required supply air temperature of 19 °C) in the occupants' zone--the area that matters most. Hence, the engineers learned from numerical values and vivid graphical profiles (Fig. 5) that the mixed system had to supply cooler air at higher velocity in order to balance the warmer air around the lighting fixtures in the ceiling level.

Fig. 5. CFX provided CFD cross-sectional profiles of air velocity, which scales from 0.02 m/s (blue) to 0.20 m/s (red), in the displacement cooling scenario (left) as well as the mixed cooling scenario (right), graphs courtesy of Olof Granlund.

3.3.2 Life-cycle cost analysis

The HUT-600 project consultants employed Olof Granlund Oy's BSLCC software to project the operation and maintenance costs of project alternatives throughout the facility's expected life span. The consultants and the construction managers shared their respective knowledge from past projects, facility management data, and manufacturers' catalogues to estimate energy consumption costs, maintenance costs, and immediate investment costs (Fig. 6), which all together provided reliable quantitative decision supports for selecting the mechanical system, choosing electrical lighting and maintenance methods, and qualifying bid packages from air handling unit manufacturers.

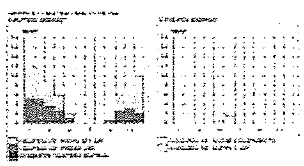

Fig. 6. RIUSKA projected the annual heating and cooling energy consumption for HUT-600 (graphs courtesy of Olof Granlund).

In the mixed versus displacement cooling analysis, HUT-600 consultants assumed the systems had a 50-year service life span. For both alternatives, BSLCC read the automatically generated bill of materials from the object-oriented applications, estimated the cost of initial investment, and projected operations costs based on energy consumption and system efficiency. With the analysis tool, the consultants also accounted for the maintenance cost, replacement cost, financing cost, as well as inflation cost. The in-depth comparison results informed the decision makers that the equivalent annual cost of the displacement air-conditioning system was 6% higher than that of the mixed air-conditioning system.

3.3.3 Environmental impact analysis

With Olof Granlund Oy's BSLCA software, the building system consultants conducted environmental impact assessments to evaluate the environmental influence of the building materials and the estimated energy consumed by the facility. In particular, the consultants extracted the material properties and quantity information from the product models of the alternative designs. They deduced the level of environmental impacts to air and water and subsequently, they quantified the amount of pollution emission, global warming, acidification, etc., in support of material and system comparison (Fig. 7).

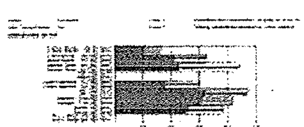

Fig. 7. Chart from an environmental impact analysis showing the weight of emission (units in y-axis brackets) from energy consumption (blue) and the building materials (green) over a 50-year period in HUT-600 (chart courtesy of Olof Granlund).

Iteratively, the designers, consultants, and construction managers evaluated and counter-proposed materials, structural systems, and building systems among themselves to balance aesthetics, performance, cost, and environmental impacts during the project design phase.

3.3.4 Lessons from HUT-600

Shared among the owners and the project team of HUT-600 was a committed belief in capitalizing on early project opportunities to make a lasting and positive effect on the facility over its total life span. Leveraging the reduced design time and improved data exchange that were enabled by the PM4D approach, HUT-600's project team was able to complete a series of life-cycle studies within the original design schedule. Pertinent decision factors and project alternatives were available during the early schematic design phase when making a decision had a relatively high impact and low cost.

In a nutshell, modern technologies are capable of expediting conventional design practices and promoting life-cycle approaches. Project experiences from the HUT-600 construction pilot demonstrated that owners are empowered to choose among comprehensive life-cycle alternatives and to align the long-term facility values with their strategic plans, whereas project team members can differentiate themselves from their competitors with higher efficiency, better quality, and more effective application of their expertise.

4 Barriers to better AEC decision making

Based on our application experience with the industry test cases, we assess that VDC technologies are promoting and automating the informative formulation of AEC decision alternatives. However, as we illustrate in the following case studies taken from the retail complex project, the high-level, predetermined, and static evaluation means and theories are hindering the clear and flexible evaluation of AEC alternatives; whereas the coupling of options and the discarding of seemingly invalid options adversely impact the quick re-formulation of AEC decision alternatives.

4.1 Evaluation barriers

For evaluating the conformity of each alternative with respect to the criteria (i.e., the owner's budget and milestones), the project executive in the retail complex project utilized spreadsheets and slide presentations to represent a predetermined set of performance predictions (Fig. 8). As the project developers evaluated the performance predictions against the decision criteria, they realized that they needed to compromise their turnover requirement to alleviate the budget problems with the acceleration alternative. Please note that this example is realistic, yet fictitious, i.e., it is based on our observations of the decision-making process and use of VDC technologies, but did not happen in exactly this way.

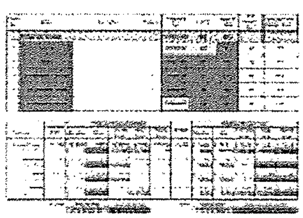

Fig. 8. Current SimVision "executive dashboard" (top) and spreadsheet-based evaluation (bottom) treat each alternative as a new field/case. They neither show the interdependencies among the alternatives nor allow the decision makers to query or evaluate alternatives at the options level.

In Section 2.2, we explained that the quality of evaluation is dependent on the means and methods to provide decision makers with pertinent decision contents and that the means and methods have to be clear and flexible. In the retail complex project, the evaluation was predetermined, static, and limited to a high-level comparison of alternatives. The predetermined table of evaluation treats all alternatives equally as independent choices; it does not differentiate whether the choices can be taken together or are truly independent. It does not show the immediate and ripple effects of a particular option on other options. The comparison is inflexible to shift among different decision foci (e.g., from the overall steel acceleration performance predictions to the predictions of the retail steelwork). It restricts the evaluators from querying the performance predictions of individual options (e.g., the time and cost impact of using one versus two or three welding teams). Furthermore, it is passive and requires manual efforts to generate and update.

4.2 Re-formulation barriers

Similarly, as the decision makers came to a trade-off conclusion, they relaxed their turnover requirement for some of the buildings. With this new refinement of the decision criteria, numerous pre-coupled options had to be reconsidered. In particular, the decision makers wondered what would be the resulting schedule, cost, and risk impacts of changing one process option by adjusting the construction sequence between the lower parking structure and the retail steel from finish-to-start to a parallel execution. While one could describe the pre-coupled acceleration schedule rather easily with state-of-the-art POP models in the CIFE iRoom, the meeting participants could not test individual project options (e.g., whether to go overtime or not for steel erection, use a finish-start or parallel sequence, etc.) and thereby obtain the ripple responses of these isolated changes on their cross-disciplinary performance predictions such as cost or schedule impacts. Even a minor change or testing of an isolated option's effectiveness requires a new set of product, process, organization, and cost linkages--a lengthy and intensive procedure that hinders "what-if" analyses.

The meeting participants wanted to test "what-if" scenarios with individual options in new combinations and evaluate the predicted performance as well as the interdisciplinary consequences. Since it would take a considerable amount of time to change the pre-coupled models with various VDC tools, the decision facilitators could only intuitively discuss the merits of each option verbally, dismiss the meeting, regenerate the VDC product/process/organization/cost models, and then cross-link them all over again before quantitatively assessing the performance predictions with the decision makers.

As Section 2.3 discusses, quick and direct re-formulation of project alternatives is pivotal to the generation of multiple and creative alternatives. The coupling mechanism and the abandonment of invalid options may seem appropriate when decision facilitators formulate alternatives. The retail complex case study shows that criteria change with new states of information, the presence of a decoupled set of options--both valid and seemingly invalid ones--might be useful to support "what-if" analysis. Current POP modeling and simulation tools require some time (a few hours or a few days depending on the size and complexity of the POP models needed for a particular decision) and resources (a few applications) to isolate particular project options and re-formulate a new alternative using various VDC tools in the iRoom during "what-if" analyses.

4.3 Decision contents and challenges

Coming up with a good action plan in AEC requires informative formulation, clear evaluation, and quick re-formulation. In current practice, there are no formal means of representing the different types of decision contents (which include options, alternatives, predictions, and criteria), which are relevant but are dispersed among the multidisciplinary stakeholders. Decision contents are the information basis for AEC decision making. The complexity and variety of dispersed decision contents, along with the dynamic decision-making process as well as the many stakeholders, present challenges for achieving the decision-making objectives that are described in the previous section. We distinguish four types of content that go into the multidisciplinary and iterative decision making process. These content types are project options, project alternatives, performance predictions, and decision criteria.

4.3.1 Options (product, process, organization, and resource options)

Project options are intradisciplinary interventions. They are heterogeneous because they may include product options (e.g., a three-level or a five-level parking structure), process options (e.g., finish-to-start relationship or a start-to-start concurrent relationship; an 8-h work day or an 11-h overtime work day), organization options (e.g., employing one, two, or three welding teams), and resource options (e.g., using one set of formwork or two sets of formwork).

4.3.2 Alternatives

An assembly of intradisciplinary options yields a project alternative, which is a coherent project plan that addresses interdisciplinary factors. Examples of project alternatives include a concrete acceleration alternative, a structural steel acceleration alternative, and a hybrid acceleration alternative. Each of these alternatives specifies a unique combination of options.

4.3.3 Predictions

Modeling, simulating, and estimating the behaviors of a coherent project plan allow decision makers to assess the performance of a project alternative with both quantitative (e.g., cost estimate and schedule) and qualitative predictions (e.g., risk concerns).

4.3.4 Criteria

The quantitative and qualitative predictions in turn allow the decision makers to evaluate the anticipated performance of an alternative against the explicitly predefined purpose, priorities, preferences, and goals that are part of the decision criteria (e.g., specifications, milestone, and budget).

The handling of decision contents relies on the ad hoc and implicit knowledge of the professionals and thus undermines the information basis, evaluation clarity and flexibility, as well as the quickness of re-formulating new alternatives. State-of-the-art VDC technologies describe each alternative as a set of pre-coupled options by interlinking information views from different disciplines. While this linkage has the potential to contribute to a balanced representation, and thus comprehension, of a particular project alternative during the decision-making process, the inability to decouple pre-coupled options hinders the effectiveness of formulating, evaluating, and re-formulating project options and alternatives to address the changing scope, cost, schedule, and organizational needs or opportunities.

Current theory offers a qualitative framework and concepts that foster value-adding decision making. The realization of its benefits depends on the stakeholders involved, the processes undertaken, and the means to handle complex and heterogeneous decision contents. AEC information-processing theories do not support the integrated representation of product-organization-process-resource options and their inter-relationships, nor do they explicitly differentiate the characteristics of options, alternatives, predictions, and criteria for decision support. For instance, theories about value engineering [4,5,11] as well as time/cost tradeoff methodologies [12-14] deal with specific option types and neglect the multidisciplinary relationships or ripple effects among AEC options. On the other hand, the Critical Path Method [14] considers options on an isolated basis as it centers on the management of risks and uncertainty of a specific project alternative. Hence, current theory is lacking a formal means to support the synthesis (i.e., the representation, differentiation, organization, preservation, and manipulation) and evaluation of decision contents (i.e., valid and seemingly invalid options, alternatives, qualitative and quantitative predictions, and criteria) in an integrated reference model throughout the many phases of AEC decision making.

Hence, the challenge is to keep the stakeholders (particularly the decision makers) informed of all the contents (particularly the options and the decision criteria) during all phases of the decision-making process (particularly the briefing and analysis phases). There are strong needs for an integration of contents that is resourceful and transparent, such that the stakeholders can comprehend the issues at stake with good information breadth; evaluating the alternatives with clarity, focus, and flexibility; while re-formulating new alternatives with quickness and repeatability.

4.4 The decision dashboard approach

Building on POP models, we are developing a Decision Dashboard that is both a synthesizer and a visual interface with the decision contents. The Decision Dashboard is not a tool for automatic generation or coupling of project options, but a visual and interactive tool for the synthesis of ideas, predictions, and requirements among AEC stakeholders. To carry out the synthesis function, we are developing a schema and a new relationship set for the Decision Dashboard to handle heterogeneous decision contents, which are represented by Decision Objects and Functional Requirements Objects. Based on the attributes within and the relationships across these representation agents, the Decision Dashboard constructs a Decision Network, an interactive graphical network.

We anticipate that the Decision Dashboard will reduce the need to couple options or discard seemingly invalid decision contents; foster better decision foci through clear and flexible evaluation; and enable efficient manipulation of various decision contents on capital projects.

5 Conclusions

In conclusion, the decision basis in AEC requires informative formulation, clear evaluation, and quick re-formulation of alternatives. We illustrate the benefits of VDC technologies in support of informative formulation through explanation of POP modeling, the iRoom infrastructure, and the PM4D approach. Assessing the limitations of current theories and tools to support clear evaluation and quick re-formulation of alternatives, we motivate the research needs of a Decision Dashboard, which synthesizes heterogeneous decision contents (i.e., options, alternatives, predictions, and criteria) to support the formulation, evaluation, and re-formulation of AEC alternatives.

Acknowledgements

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These content types are project options, project alternatives, performance predictions, and decision criteria.4.3.1 Options (product, process, organization, and resource options)Project options are intradisciplinary interventions. They are heterogeneous because they may include product options (e.g., a three-level or a five-level parking structure), process options (e.g., finish-to-start relationship or a start-to-start concurrent relationship; an 8-h work day or an 11-h overtime work day), organization options (e.g., employing one, two, or three welding teams), and resource options (e.g., using one set of formwork or two sets of formwork).4.3.2 AlternativesAn assembly of intradisciplinary options yields a project alternative, which is a coherent project plan that addresses interdisciplinary factors. Examples of project alternatives include a concrete acceleration alternative, a structural steel acceleration alternative, and a hybrid acceleration alternative. Each of these alternatives specifies a unique combination of options.4.3.3 PredictionsModeling, simulating, and estimating the behaviors of a coherent project plan allow decision makers to assess the performance of a project alternative with both quantitative (e.g., cost estimate and schedule) and qualitative predictions (e.g., risk concerns).4.3.4 CriteriaThe quantitative and qualitative predictions in turn allow the decision makers to evaluate the anticipated performance of an alternative against the explicitly predefined purpose, priorities, preferences, and goals that are part of the decision criteria (e.g., specifications, milestone, and budget).The handling of decision contents relies on the ad hoc and implicit knowledge of the professionals and thus undermines the information basis, evaluation clarity and flexibility, as well as the quickness of re-formulating new alternatives. State-of-the-art VDC technologies describe each alternative as a set of pre-coupled options by interlinking information views from different disciplines. While this linkage has the potential to contribute to a balanced representation, and thus comprehension, of a particular project alternative during the decision-making process, the inability to decouple pre-coupled options hinders the effectiveness of formulating, evaluating, and re-formulating project options and alternatives to address the changing scope, cost, schedule, and organizational needs or opportunities.Current theory offers a qualitative framework and concepts that foster value-adding decision making. The realization of its benefits depends on the stakeholders involved, the processes undertaken, and the means to handle complex and heterogeneous decision contents. AEC information-processing theories do not support the integrated representation of product-organization-process-resource options and their inter-relationships, nor do they explicitly differentiate the characteristics of options, alternatives, predictions, and criteria for decision support. For instance, theories about value engineering [4,5,11] as well as time/cost tradeoff methodologies [12-14] deal with specific option types and neglect the multidisciplinary relationships or ripple effects among AEC options. On the other hand, the Critical Path Method [14] considers options on an isolated basis as it centers on the management of risks and uncertainty of a specific project alternative. Hence, current theory is lacking a formal means to support the synthesis (i.e., the representation, differentiation, organization, preservation, and manipulation) and evaluation of decision contents (i.e., valid and seemingly invalid options, alternatives, qualitative and quantitative predictions, and criteria) in an integrated reference model throughout the many phases of AEC decision making.Hence, the challenge is to keep the stakeholders (particularly the decision makers) informed of all the contents (particularly the options and the decision criteria) during all phases of the decision-making process (particularly the briefing and analysis phases). There are strong needs for an integration of contents that is resourceful and transparent, such that the stakeholders can comprehend the issues at stake with good information breadth; evaluating the alternatives with clarity, focus, and flexibility; while re-formulating new alternatives with quickness and repeatability.4.4 The decision dashboard approachBuilding on POP models, we are developing a Decision Dashboard that is both a synthesizer and a visual interface with the decision contents. The Decision Dashboard is not a tool for automatic generation or coupling of project options, but a visual and interactive tool for the synthesis of ideas, predictions, and requirements among AEC stakeholders. To carry out the synthesis function, we are developing a schema and a new relationship set for the Decision Dashboard to handle heterogeneous decision contents, which are represented by Decision Objects and Functional Requirements Objects. Based on the attributes within and the relationships across these representation agents, the Decision Dashboard constructs a Decision Network, an interactive graphical network.We anticipate that the Decision Dashboard will reduce the need to couple options or discard seemingly invalid decision contents; foster better decision foci through clear and flexible evaluation; and enable efficient manipulation of various decision contents on capital projects.5 ConclusionsIn conclusion, the decision basis in AEC requires informative formulation, clear evaluation, and quick re-formulation of alternatives. We illustrate the benefits of VDC technologies in support of informative formulation through explanation of POP modeling, the iRoom infrastructure, and the PM4D approach. Assessing the limitations of current theories and tools to support clear evaluation and quick re-formulation of alternatives, we motivate the research needs of a Decision Dashboard, which synthesizes heterogeneous decision contents (i.e., options, alternatives, predictions, and criteria) to support the formulation, evaluation, and re-formulation of AEC alternatives.AcknowledgementsWe thank the following people and their associates for their invaluable help in sponsoring the work reported in this paper, providing access to projects and VDC technologies and methods, and supporting VDC modeling and analysis of the projects: Ari Ahonen, Peter Allen, Jim Bedrick, Phil Bernstein, John Chachare, Reijo Hänninen, Curtis Johnson, Auli Karjalainen, Arto Kiviniemi, John Kunz, Jarmo Laitinen, Seppo Lehto, Wendy Li, Mark Liew, Kathleen Liston, Tom McKinley, Charlie Kuffner, Al Moulton, Xiaoshan Pan, Jes Pederson, Dean Reed, Melody Spradlin, John Taylor and Emre Terazi. 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ABSTRACT

This paper explores the design of visualizations that support mandated organizational compliance processes. We draw on the research literature to show how visualizations can operate as effective user interfaces for complex, distributed processes. We argue that visualizations can reduce the complexity of such processes, making them easier to manage, and can facilitate the communication and collaboration that are critical to supporting compliance. We describe the design and pilot deployment of a visualization that supports the IBM Sarbanes-Oxley Act compliance process, discussing design alternatives, the final design, its deployment, and lessons learned. [PUBLICATION ABSTRACT]

FULL TEXT

This paper explores the design of visualizations that support mandated organizational compliance processes. We draw on the research literature to show how visualizations can operate as effective user interfaces for complex, distributed processes. We argue that visualizations can reduce the complexity of such processes, making them easier to manage, and can facilitate the communication and collaboration that are critical to supporting compliance. We describe the design and pilot deployment of a visualization that supports the IBM Sarbanes-Oxley Act compliance process, discussing design alternatives, the final design, its deployment, and lessons learned.

INTRODUCTION

Since the advent of the Sarbanes-Oxley Act (SOX), which established new or enhanced standards for corporate accountability, systems for tracking and managing compliance testing have become critically important to organizations. One of the challenges to designing such systems is managing the interface between people and the system's computational processes. By their very nature, compliance systems require that humans monitor processes and investigate and fix problems: There is no such thing as an "automatic" compliance system. The point of a compliance system is to ensure that humans are involved, because ultimately one or more persons must take personal and legal responsibility for compliance. Another challenge is the fact that, in an organization of any appreciable size, monitoring and other activities are likely to occur among a number of people in disparate locations. These challenges are compounded by the fact that human performance differs from that of computers: People are prone to make a variety of errors of perception and calculation, including forgetting to enter information, neglecting to enter it in a timely fashion, and sometimes overlooking items. In short, compliance management systems are complex sociotechnical entities whose smooth functioning involves a blend of technical, human, and social factors.

Our concern is with the design of socio-technical systems that span large organizations. In this paper, we report on the design and use of a shared, dynamic visualization of organization-wide processes to aid tracking and managing compliance. We argue that the use of a visualization can amplify human cognition at an individual level, and that when it is visible to all participants, it will evoke social processes that can aid in managing compliance. At the same time, the shared nature of the visualization means that privacy becomes a key issue for ethical, cultural, and legal reasons, and so the design of the visualization involves making careful choices about the circumstances under which information is made visible to others.

MANAGING RISK AND COMPLIANCE

While there are a number of eminently practical reasons that companies should be concerned with managing their risks, the current interest in this domain is driven by recent legislation by the United States Congress. It is useful to understand this legal context, as it is the direct driver of the current push to devise better tools to support risk and compliance.

The Sarbanes-Oxley Act

SOX was signed into United States law on July 30, 2002, largely in response to a number of major corporate and accounting scandals. It establishes new or enhanced standards for corporate accountability. All publicly traded companies in the United States need to comply with this legislation. The scope of the law and the nature of the controls it specifies mean that compliance requires considerable work on the part of companies. In view of this, SOX is being put into effect on a staggered schedule, each section going into effect on a different date. The following are the main sections of the law:

* Section 302/906-Corporate Responsibility for Financial Reports

* Section 404-Management Assessment of Internal Controls

* Section 409-Real-Time Issuer Disclosures

* Section 802-Records Management

Section 302 of SOX is already in effect. To comply with section 302, the chief financial officer (CFO) and chief executive officer (CEO) must personally certify the accuracy of financial statements and the efficacy of internal disclosure controls. Disclosure controls must be established and enforced at all levels within the company, with quarterly evaluation of the efficacy of controls by the company. All significant deficiencies, material weaknesses, and acts of fraud must be disclosed to the audit committee. The company must establish and emphasize a culture of integrity, and the CEO and CFO must have confidence and trust in the people and process.

Section 404 for accelerated filers (companies with a public float greater than $75 million) went into effect in November 2004. For nonaccelerated filers, the date has been extended to July 2007. It requires that management file annual reports on internal controls, and that these reports be attested to by external audit firms. All controls relating to financial reporting must be documented and tested for efficacy. All gaps and deficiencies of such controls must be reported. Companies must demonstrate an ability to monitor control compliance.

Sections 409 and 802 are not yet in effect. The ongoing implementation of section 404 and the pending implementation of sections 409 and 802 suggest that the way organizations manage their risk and compliance processes will be in flux for the near future, and that, in turn, there will be a significant need for approaches that facilitate an organization's ability to deal with these issues.

Before the advent of SOX, IBM already had a welldefined control process. This process was further developed to support SOX, and particularly SOX 404 reporting, the latter focusing on management oversight of internal controls, including quarterly evaluation of each control.

By the time we started working with the IBM controllers, all the controls had been identified and categorized by business process and by country. For example, one control-in the Accounts Receivable process category-requires that adjustments be checked to ensure that management has approved all adjustments that are not financial in nature; this control is tested in several countries, including Argentina, Australia, Austria, Belgium, and Brazil.

As one would expect, the process of testing controls is not automatic. Even if this were possible, it is not desirable, because SOX requires that individuals take personal responsibility for certifying the accuracy and efficiency of the control processes. Thus, people are an integral part of the system. Each process has an owner who monitors the set of controls in effect for that process (a process owner may own several processes); each country has an owner who monitors the controls for that country; and each control has an owner who is responsible for seeing that the appropriate number of tests are run each quarter (or each testing period) and that defects are investigated, reported, and remediated. Process owners are responsible for coordinating the people who own their process controls and for determining that the defects are real, rather than a problem with the control itself.

Monthly reporting from the globally distributed owners for each control is supported by a formbased front end to a database, and all control information is stored in the database. A quarterly scorecard is generated that provides summary information about the control status, such as the number of unremediated defects since inception to date, the number of defects for the current quarter, and the number of samples for the current quarter. The scorecard is rolled up by business unit and business process.

Overall, IBM monitors on the order of hundreds of controls spanning dozens of countries (though not every control is relevant to every country). This generates a significant amount of data, and the problem of managing it is nontrivial, particularly because of the dynamic and distributed nature of the controls and control-related information.

IMPORTANCE OF VISUALIZATION

This section addresses why visualization is a promising approach to compliance management. This discussion draws on work in the field of social computing (e.g., Erickson and Kellogg and Olson and Olson2).

The term visualization might refer to a wide range of representations, from static depictions of data to full interactive applications. We primarily discuss interactive visualizations, though some or even many of the cognitive, motivational, and social benefits of visualizations that we discuss could be realized as static displays. However, in most cases the benefits are enhanced when the user has the ability to filter, interact with, and manipulate the data. In the section "Lessons Learned," we contrast dashboards (a static representation and not always of visualized data) with interactive visualizations. For an interesting example of an interactive visualization, see Reference 3.

Visualization at the individual level

There is a large body of research literature on information visualization and the cognitive effects of perceiving and conceptualizing information; summarizing it is beyond the scope of this paper.

Instead, we draw on the categorization and explanation of the benefits of visualization by Card et al., particularly how visualizations can increase people's visual capabilities and amplify cognition.4 They outline six ways in which visualizations can provide benefits: (1) by increasing memory and processing resources available to the user, (2) by reducing the search for information, (3) by enhancing the detection of patterns, (4) by enabling perceptual inference, (5) by using perceptual attention mechanisms for monitoring, and (6) by encoding information in a malleable medium.

Cognitive psychologists have built up an empirical picture of these benefits over the last 30 years. For example, visualizations can increase working memory and the cognitive processing resources available to a user because some visual elements can be processed in parallel by the (relatively fast) human perceptual system; some work that would otherwise be performed by the slower and limitedcapacity cognitive system can be offloaded to the perceptual system; and keeping pertinent details "in the world" rather than in the user's head can increase the amount of working memory that can be devoted to problem solving.7

Visualizations can reduce the effort needed to search for information because they are dense, portraying a large amount of data in a small space. They can enhance pattern detection through aggregation and abstraction of data (when this is combined with the ability to focus down to details, it can be particularly effective). Visualizations support perceptual inference, making some problems obvious and allowing a large number of elements to be monitored. Finally, when visualizations are interactive and malleable, they can be directed by users to examine particular areas of interest.

Visualization for groups

Visualization is also a powerful tool when used by groups of people to collaborate, particularly across distances. Erickson and Kellogg use the concept of social translucence to explain why this is so: Visualizing people and their activities leads to awareness and mutual accountability. Socially translucent systems create common resources by which people can more effectively coordinate their behavior. Such systems also support the emergence of social dynamics-such as peer pressure, imitation, the creation of norms, accountability, and other phenomena-that help to motivate collective effort toward common goals. In a series of studies of a socially translucent group-chat tool called Babble, Erickson and colleagues documented several effects on group process, including encouraging informal expression, minimizing the social overhead required for information exchange, and allowing remote members to keep in touch and quickly reestablish context.10,11

Similar social dynamics can emerge from information visualizations. Erickson et al. describe the task proxy, a visualization of the state of a task by individuals throughout an organization. In this representation, information about the task is in the foreground, so that its overall state can be discerned at a glance, but the elements of the task state reflect whether individuals have completed their bit of the task or not. Exposing such a visualization to the people in the organization generates social dynamics, such as peer pressure ("I'd better get this done; I'm almost the last one"), requests for assistance ("I see Tessa is already done; I'll ask her if the update messed up her system"), or offers of assistance ("No one in John's group has started on this; I'd better let them know"). The visualization provides a mirror to the organization of its own behavior and common ground for task participants to discuss what is happening and to coordinate task completion.

Halverson and colleagues have taken a similar tack in creating a customizable interactive visualization for bug-tracking data in software development (see Reference 13 for a screen capture of the actual visualization). This visualization supports software developers and project managers in managing both technical and social issues. It does this because the visualization is compact, yet allows users to monitor for problems throughout an extremely large data set (over 10,000 bugs), and when shared among all the development team members, this visualization provides a basis for negotiating the priority of various bug fixes.

DESIGN PROCESS

The process of designing and deploying the risk and compliance visualization spanned almost two years. In this section, we describe the basic methods brought to bear on the process and the participatory approach we used to develop and deploy the design.

Figure 1 provides a high-level overview of the types and distribution of methods involved, and their relationship to the deployment. The key points illustrated by the figure are that we employed a number of different methods to advance the design process and that the different methods were often pursued in parallel (although there is a tendency for those in the upper portion of the figure to be used earlier than those in the lower portion of the figure). While it is not uncommon for design to be portrayed as a linear process, in our experience, such interleaved parallel activity is the usual case, especially when the design process involves working with multiple stakeholders in various organizations, as this one did (see Reference 14). Some activities, such as design experiments, can be started immediately by members of the core team, whereas others, such as structured interviews, may require lead time to set up (arranging to interview the CEO of a major financial institution can require considerable political work as well as waiting for an opening in his or her schedule), and still others, such as deployment, may be constrained by organizational processes.

Methods used

We began by familiarizing ourselves with the design territory. In addition to reading background material and literature, we interviewed people involved in compliance management. In parallel, we began a series of design experiments, which helped us develop a sense of the possibilities afforded by visualization techniques. We then implemented an early technical prototype and moved fluidly between design experiments, technical prototype development, and design conversations with our users and stakeholders. This work eventually culminated in a deployment, although we continued our other activities.

Structured interviews

We used structured interviews early in the design process to learn how IBM executives were thinking about risk and compliance. These interviews helped us understand the risk and compliance domain in general and the concerns of executives (who, under SOX 302, must certify the compliance process) in particular. The executives were primarily concerned with achieving a standard and unified approach to controls testing and reporting processes used in different parts of the organization. They viewed unification as essential if they were going to be able to monitor, manage, and track the controls testing data for the current quarter.

Design experiments

Learning by creating visualizations was an important part of the design process. Some visualizations took the form of quick sketches to explore an idea, such as exploring how to present a high-level view of an organization's compliance. Others were detailed explorations of a particular design feature; for example, we created four alternative designs to explore how to represent the state of compliance of a business process, and we did a series of sketches to investigate how to structure the compliance representation to best reveal interesting patterns in the data. We used storyboarding techniques to explore the details of interactions through a particular use of the visualization. For example, we created a storyboard to demonstrate to IBM controllers how they would use a compliance visualization to identify and focus on a particular defective control that needed attention.

Design conversations

We held detailed conversations with end users and stakeholders about specific design problems. The conversations ranged from e-mail exchanges to semiformal meetings, and topics ranged from general issues to discussions focused on a specific design issue, storyboard, or iteration of a design solution. For example, after meeting with controllers to learn about their process and discuss the design problem, we exchanged e-mails in which we asked specific questions about their process, such as how it was represented and encoded in the controls database, how they used the controls database to support their process, and their scheme for numbering controls.

Technical prototypes

To ensure that our designs were technically feasible, we built working prototypes of some that we were considering deploying. Many were user-interface prototypes to explore the interactions we were proposing. We also conducted studies of how to structure the Extensible Markup Language (XML) from which the visualizations are generated. Finally, we used our technical prototypes to investigate performance and communication between the underlying analytic components and databases that we were intending to use.

Participatory approach

Our purpose was to create visualizations that would support real-world risk and compliance processes. As a consequence, it was critical to deploy our prototypes to the actual people who would be using the real system and to provide access to the actual data.

Doing this introduced a number of difficulties. The real nature of the work and the demands of the organizational contexts in which it took place often shaped what we did and how we had to do it. For example, because of the quarterly financial cycle, our prototype had to be ready to deploy for the fourth quarter, even though it was not as fully featured as we would have liked. Running a prototype against the actual SOX database was another challenge. The technology staff who hosted the SOX database was unwilling to let us deploy technology on their working server, and so we had to run against a replicated copy of the database. This limited our ability to create a visualization that reflected up-to-the-minute information in the database, as we could replicate only twice a day without affecting database performance. Although we were reassured by the executive controllers that the update frequency was sufficient, it proved to be insufficient for other stakeholders in the controls process.

Furthermore, we wanted the controllers to feel that they owned this system. That was one reason that we involved them early, engaging them in interviews and in conversations about various design experiments and technical prototypes. In addition, we decided that we should make use of their process for deploying new technology. Thus, although we hosted the prototype on our server, they created the training materials for it, announced it, and distributed it by means of a link from the corporate controls Web site.

WORKING VISUALIZATION

Our goal was to create an interactive picture to capture and summarize compliance data. We wanted users to see at a glance the processes and controls that needed further investigation. A good visualization should reveal patterns in the data that are important for understanding the current state of the compliance process and the actions that need to be taken. For example, the visualization should make it easy to see common controls tested in different countries that have unremediated defects or to see controls that repeatedly have remediated defects each testing period. It should then be possible through interaction with the visualization to obtain the information needed for necessary action on the part of the user, such as contacting the person responsible for a control.

Rationale

We anticipated that a visualization would support the monitoring of control status and the analysis of patterns of defects. In particular, a visualization should enable stakeholders in the control process to answer the question, "How is our organization doing?" Rather than the typical dashboard approach of providing a high-level summary to answer this question, we thought that it was important to provide a picture so that people could actually "see" how the organization was doing. This was accomplished by two tactics: using small colored shapes to represent the data of interest and grouping the data closely together so that visual comparisons were facilitated. Thus, for example, grouping controls by business process would allow people to monitor a particular process and to compare that process with others.

These tactics were critical to support monitoring and pattern recognition throughout this large data set. Pattern recognition is a central benefit of visual processing, and an appropriate visualization can support this process, changing the task from a cognitive one to a perceptual one.6 A visualization that contains a visual representation of each control and groups these controls along dimensions that are important for the control process should make it easier to spot patterns in the control data. Patterns that could be shown in a compliance visualization include processes with defective controls, controls with defects that have the same control process but are run in different countries, and repeated control defect-remediation cycles.

Although it is important to get an overview of the entire data set, it is also essential to be able to restrict the view in order to see more detail. Thus, filters are important so that more specific questions can be asked. Time and place are always important and allow for such questions as: "How is the United Kingdom doing?" and "How did we do last month?" Similarly, specific information about a process or control is also necessary to follow up on observed problematic patterns. Thus, clicking on different parts of the visualization should reveal more information.

Deployed prototype

Figure 2 is a visualization for the IBM SOX compliance process. (It is for illustration purposes only; the data is fictitious.) At the top is a gray header that contains the legend, a "View By" dropdown menu, and check boxes that allow the user to configure the control types shown in the visualization. Below the header, the screen is divided into three columns. The first column (left) contains a scrollable list of business processes ordered alphabetically. (In actuality, there are approximately 150 business processes.) Each colored shape represents a control for that process. Shading indicates whether the control had a defect the previous quarter, and its color indicates its status. The second column (middle) provides a more detailed view of a single process: It shows the controls for a selected process broken down by country. The third column (right) provides a view of the details of a single control. Thus, the visualization shows, from left to right, a view of all processes, a view of all controls of a single process broken down by country, and the details of a single control within a process.

An executive viewing the processes in the first column might wish to explore the topmost process, Accounting, noting that it has four magenta controls (i.e., controls with defects), and a number of other controls that are under-tested (yellow) or have no data at all (gray). Selecting this process would provide an expanded view of it in the middle column (as shown), with its controls grouped by country. Thus, the executive could quickly see that-while the controls in Italy, the United Kingdom and the United States are in fairly good shape-Canada, China, Denmark, and Spain give more reason for concern.

When the executive clicks on a particular control in the middle column, the details for that control appear in the right column. These details include a description of the control and the root causes and action plans for any defects. The control that is selected in the figure is in Denmark and is indicated by a heavy blue border around the shape. Its details are shown in the right column. Some other controls in the middle column (in Canada and China) are also highlighted by a thin black border. These represent the same control, but run in different countries. These controls are also listed at the bottom of the right column.

From the drop-down menu on the left, the user can group the controls in the first column either by the business process, as shown in the figure, or by country. When the left-column view is by country, the middle column becomes a breakdown of the controls for the country by process. Using the check boxes, the user can turn the display of controls of a certain status or type on and off. Thus, for example, the user might choose not to show controls that are fully tested, and when he or she unchecks that option, the green squares are not shown in the visualization.

The end result is an interactive visualization that shows aggregate status at one instant with the ability to selectively explore particular elements in greater detail. A consequence of this approach is that users will have to negotiate a learning curve to interact with the visualization effectively. Without some training and experience, they may find it difficult to understand the significance of what is shown, to navigate the data, or to best configure the visualization to serve particular needs.

DEPLOYMENT

The deployment took place between December 2005 and February 2006. The deployed version was written in Squeak (an open-source version of Smalltalk) and required downloading a plug-in. The availability of the compliance visualization was announced on the front page of the IBM corporate controls Web site, and there was a link (with a "NEW" bubble icon) to a page describing the visualization and the pilot deployment. The visualization was updated twice daily with a current snapshot of control data.

Because we ran the pilot near the close of a financial quarter-a very busy period for our users-the pilot involved only 20 participants. The global controls coordinators, both those responsible for particular processes worldwide and those who were responsible for particular countries, were the main participants. They are responsible for monitoring the controls for a specific process or set of processes, or a specific country or set of countries.

We used a number of methods to collect feedback. First, a "Provide Pilot Feedback" button on the visualization (see Figure 2) was used to point the participants to a wiki where they were able to provide written feedback. second, we interviewed seven of the controls-process and country owners who participated in the pilot deployment. Third, we conducted an online survey that gathered input from seven different controls-process and country owners, asking them about their role in the controls process, their experiences using the controls database and scorecard, and their feedback on the visualization. Finally, we talked to the controls process executive team-the group that provided input during our participatory design processabout the deployed design.

LESSONS LEARNED

In this section we report on the lessons learned to date, based on the nearly two years of work described herein. This is a work in progress and is directed toward a very particular situation. Nevertheless, we believe that these observations can provide value to others pursuing similar efforts.

Visualizations as user interfaces to control tasks

A visualization should be thought of as a user interface to a control task, not as a report or a report component. The visualization was designed to support the controllers, and in particular, the team of controllers who were overseeing the SOX controls process. It was this team that participated in our design process, and consequently, their needs and influences shaped what we produced. When we were doing our design work, they were looking for a reporting solution, that is, a view that would substitute for the quarterly scorecard which they used to summarize their data. Because their main interest was in seeing compliance status across all their processes, we chose not to support the input of control data in the prototype, but, we learned this did not serve the needs of other controllers. Several controllers who did not participate in the design process reported that while they liked the visualization that provided an overview and allowed them to see the controls status and compare global controls across countries, they still needed access to the database. As one informant said, "Any time I see something that doesn't look right, I need to do something."

From our post-pilot interviews and surveys of the participants, we learned that the controls testing, monitoring, and reporting tasks are complex. There are many subtasks and items that need to be tracked. Examples mentioned by our interviewees include: keeping track of how many tests need to be run and at what intervals; ensuring that defects are due to particular errors, as opposed to systemic issues with that control; and tracking the e-mail exchanges about control remediations and action plans. They also mentioned other activities that occur in support of compliance management: e-mail exchanges, phone meetings, surveillance of the CFO dashboard, forays into the controls database to find out detailed information about a particular control, and filling out forms to add information to the controls database. This suggests that controllers are already using many tools and doing many small subtasks as part of their overall responsibilities. This, in turn, necessitates continual switching between tasks and tools and leads to overload and frustration. Thus, although our visualization was quite attractive to those whose primary job was overseeing the state of compliance, it was "just one more tool" to those who were involved in managing details of the process. Nevertheless, we believe that an interactive visualization of the sort we designed has promise as a single online place that controllers can go to perform compliance-related tasks. In addtion to providing input to the database, it should provide an integrated view and allow access to all the functions that controllers require. It would be even better if the visualization also provided integrated support to track the state of all the components of subtasks, even those initiated in a separate tool, such as e-mail; it would be useful if the visualization could allow controllers to see the e-mail trail for a particular control.

To create a visualization that provides this additional functionality is a considerably larger and more complex design task. The complexity is not so much due to the work of integrating the additional functionality as it is to the logistic and political issues raised by deploying an application that changes and updates the data in the actual corporate SOX database. Such changes would require that our work become an integral part of the complex and lengthy software development process for technology that is created and deployed for IBM internal business support. The decision to begin our design work with a visualization that could be pointed at a cordoned-off replica of the real data was not just due to the interests of those controllers involved in our design process; it was also a politically feasible way to integrate a research system into the core practices of a working organization.

Visualizations as landscapes

Visualizations should show a landscape, not an isolated summary view. A common type of solution to manage risk and compliance is the executive dashboard.16,17 We started our design work by exploring such dashboards. They typically provide a series of portlets that show the summary status of different aspects of a business. The Hyperion dashboard is one of the best dashboards in the industry. The executive user can view the summaries reported in these portlets to get an overview of the current status of the organization and can hone in on any problem areas. Typically, a user can click on an item and be provided with more detailed information. From our interviews with executives early in the design process and from our own experiences designing such dashboards, we learned that such summary visualizations do not provide the executive with an adequate integrated picture of the status of the organization. While the dashboard provides iconic abstractions representing the data of the individual controls, the picture of the organization that it provides is at too high a level. The patterns that are important for users to manage are at the level of the controls. For example, executives told us that they needed to be able to see which controls are failing in multiple countries, or which countries have multiple controls with open action plans. Most important, the executives told us that they needed to see the specific defective controls, as these were the ones of concern. One commented: "Here's the real issue. Let me get underneath. I look at this report and I don't know whether I'm in trouble. The fact that I have an unremediated defect is not a show stopper." Reporting the data abstracted away from the control details means that the executive must inspect each of these separate reports, determine the details, and integrate these details into a coherent mental picture. This is a lot of work.

Also, depending on the metrics used to create the visualization, the summary status can be misleading. Understanding the true status of an organization's compliance requires "seeing" the details underlying the summary. That summaries are misleading was evident in a number of our design explorations in which we attempted to use a single object to represent a whole body of processes. The downfall of this idea was that one was unable to see how many processes comprised that object. Often even the smallest of trouble spots needed immediate attention, but these small trouble spots were overpowered and lost in the status of the majority. In short, to monitor compliance, averages or other summary statistics are often not what is needed. One needs a display that brings the problem areas to the foreground and permits their immediate identification, even if they are proportionately small.

For example, in one of our initial designs, individual controls were not shown; rather a block representing the business process was shown, and the color of that block was to be determined either by averaging the status across controls or by showing the color of the control with the "worst" status. To see the status of individual controls required a mouse-over on a particular process. Even using the "worst" control status to determine the color of the process block did not give the controllers sufficient information to determine which process needed their immediate attention. Because it was important to know how many controls for a process had defects, using the average control status to determine color was not helpful either, as there might be the same number of controls with defects in a large block of magenta as in a smaller block of magenta. A heat-map visualization, by its very nature, draws attention to large blocks of magenta, whereas, for controllers, blocks of both sizes need their attention.

In response to this, we created a representation that depicted the actual controls along with the use of color to show status. With this, the controllers can visually inspect the representation and compare the relative size of the blocks of color to determine the extent to which a particular business process is in compliance. The feedback we collected suggests that this representation appealed to the controllers and was readily understood. One drawback, however, is that several controllers did complain that the control shape was too small in size, and the difference between the shapes was hard to discern. This is the downside of a landscape approach, which puts all the information on one screen.

Although our initial analysis of dashboards had led us to discount summary statistics, feedback from the deployment caused us to reconsider this position and arrive at a more nuanced understanding. Controllers told us that summary statistics do provide a useful high-level orientation. One remarked, "A graphical view would be useful in reporting if I could capture a view and put it in a status report. Sometimes you get lost in the spreadsheet numbers, where a graph can make a point a whole lot better."

Because all controls could not be seen on one screen, users wanted to know the number of controls of different status, for example, how many controls had unremediated defects. Although summaries are a good way of reporting what happened during the quarter, they are not a good approach for day-to-day management of compliance. It does not help a controller to know that four controls have defects; the controller needs to know the specific controls, who owns them, and what is being done to remediate those defects. Further, knowing that there are four controls with defects this quarter and there were four controls with defects the previous quarter does not let the controller know whether these are the same four defects, and so on. Thus, while summary statistics are insufficient on their own, they are not without value. The best solution is a combination: summary statistics that provide orienting information and a landscape visualization that provides an overview of processes and controls and a way to obtain detailed information from an integrated context.

Visualizations as part of an evolutionary process

Visualizations must be able to evolve as the process for an individual or a group evolves or as the overall compliance process evolves. While the controls database is defined to support the generic controls process, individual processes may have exceptions. For example we were told by one of the process controllers that his process is not broken down in terms of countries (as is defined by the generic process), but in terms of brands. To use the controls database, the unique structure of this process was mapped to the database structure. However, because this was done by creating an individual process for each brand, comparisons of controls across brands could not be made. Such a comparison would be useful, because the same control runs in different brands, just as for other processes the same control runs in different countries. A second example described by an interviewee is a process in which some of the controls are tested on a schedule that is different from the quarterly schedule set up in the database. This means that for some of the controls, there will be missing data one quarter, because that control is only tested twice a year. Having the visualization show "Missing Data" for that control is misleading, as the data is not missing; it is just not expected to be there. The information about how often each control should be tested is not kept in the database, but in a separate spreadsheet.

Not surprisingly, exactly what information controllers need to see depends on what they need to do. For example, executives who have responsibility for overseeing the whole control process need to have a view of all the processes and be able to see the proportion of controls with defects. They would also like to see how important a defect is in relation to financial risk. In contrast, controllers who are overseeing a specific country or process need to see just those controls for which they are responsible and the underlying details. It is these detailed views that are important to them, as they need to make sure that appropriate actions are being taken by control owners to remediate the control. Although we did not talk to any control testers, presumably they would want to see how their controls were doing, ensure that their status was accurately reflected in the database, and that no mistakes had been made in data entry.

In addition, for a particular controller or group of controllers, what they need to see and do depends on where they are in a reporting period. The work is cyclic, and the tasks change across the testing and reporting cycles. For example, controllers told us that during the quarter when they are monitoring the status of controls and checking on any remediations in progress, they need to be able to focus on the data for a particular control. At the end of the quarter, when they are reporting the results of the testing, they need to see overviews and summary information. Being able to associate the kinds of views they are looking at with a personal or organizational time line would add significant value to such a visualization.

We had assumed that the overall compliance process was defined, thus defining the visualization needed to show the patterns in the compliance data. However, we learned through our experience working with the controllers that the compliance process is continually being refined. As controllers go through the process and make use of the data, their understanding of how a compliance process might work evolves, their notion of what data can be collected changes, and they use the data to answer new kinds of questions. For example, when we interviewed process owners, they requested that trends be added to the visualization so that they could see the behavior of controls over time. They had recently started to experiment with viewing data this way and integrating trend analyses into their quarterly reports. When probed further, we learned that as the controls process had now been running for some time, there was sufficient historical data to make trend analysis worthwhile. We found this point interesting, as we had probed the importance of a historical view of the data in some of our original design sketches. However, because these design sketches had not received particularly positive reactions at the time they were presented, we had placed such views lower in our design features list.

The evolution of the controls process leads to new requirements for the visualization. This suggests that-just as the visualization needs to allow individuals and groups to create custom views to support their unique variants of the process-the overall visualization needs to be malleable as the generic controls process evolves. For example, a customizable visualization would maintain the same visual elements, but allow these elements to be associated with different organizational structures. It would also allow visual features, such as color, to be associated with different control attributes.

Visualizations as support for communication and coordination

A single picture created from a "visual language" that maps to the domain elements can support communication and coordination among people who are focused on different parts of the task and concerned with different granularities of analysis. Controllers work in teams and need to coordinate with respect to the current status of the controls. They reported that the scorecard is insufficient for coordination as it does not provide detail down to the control level. It is at the level of the individual control that problems typically need to be addressed, and communication among a control owner, country owner, and process owners about individual controls are typical. Controllers do coordinate by referencing the database to see a description of the defect. One controller pointed out that this description was missing from our visualization (a feature we needed to add immediately). Controllers also use the database for initial information on what actions have been taken regarding a particular control. Although controllers use the database in these ways, they spend a large amount of time communicating by e-mail and telephone. In particular, controllers whose responsibility it is to monitor processes or countries typically act as alerters, that is, they send an e-mail to the appropriate people when they need to attend to an issue at a particular time. Also, groups working on one process tend to have regularly scheduled status meetings to ensure that everyone is aware of any change to controls and of the progress made on problematic issues.

Our design participants felt that the visualization could support their coordination tasks and make their alerting role easier. Unfortunately, due to limitations of the deployment (too few users and too short a deployment time), we were unable to verify this. However, we believe that the visualization could be extended to better support alerting activity with the addition of alert tracking and timing features. For example, allowing the controller to specify alerts of the form: "Send an alert to Marge Johnson if control 10 is not remediated by June 24, 2006." Further evidence that such an alerting feature is important came from some process owners who stated that the visualization might reduce the number of e-mails being exchanged among those managing the overall SOX compliance process and the process owners. At the same time, they also raised the concern that such a visualization might lead to micromanagement, because it increased the desire to ensure that there would be no magenta on the display each quarter; that is, there would not be any controls with unremediated defects. They felt this would not be a good thing, as often there was a reason for a control to have an unremediated defect, and as long as that control was being managed appropriately, there was no need to bring additional pressure to bear on process owners (which would, in turn, require additional e-mails to explain what was happening). As one participant commented, "I don't need anyone looking over my shoulder. 'Missing' could be misinterpreted by someone unfamiliar with the process. [...] I don't want someone jumping to a conclusion. I don't have that concern with the scorecard because no one is looking. [But] I like this visualization a lot better than the scorecard. I like this." One way to manage this issue, explored by Erickson et al., might be to restrict the ability of users to see and communicate with owners of controls for which they are not directly responsible. Another possibility would be to refine the set of states for controls to include a classification for "unremediated but being effectively managed" controls.

The need for personalization and customized views is problematic from a social computing standpoint. For a visualization to enable coordination of work, it needs to provide a shared view of the information. This allows people to point to something on the screen and have a shared context for conversation. Once people start customizing views, the shared context is lost. As one informant put it, "I wouldn't go completely away from the canned views. They are valuable, especially where reporting, [it] is useful that everyone is looking at it the same way." For this reason, we would argue that customized views need to be shareable. Furthermore, there needs to be a single visual language used so that the concepts and objects important for SOX controllers have a single and consistent visual referent. For example, in our visualization, the visual language represents an operational control as a small circle and a defect as a magenta color. These shapes and colors can be reused in different custom views, so long as the mapping between the visual language and the domain is maintained. Thus, a process name written in magenta text, for instance, would probably indicate to all people familiar with the visual language that the process had a defect.

CONCLUSION

Visualizations can play an important role in facilitating compliance processes throughout an organization. Reducing the complexity of the process by turning cognitive operations into perceptual ones is key to this simplification. Providing a picture that can be used as a common point of reference for conversation and communication is another crucial attribute of visualizations. This is particularly important when compliance is a global process involving multiple languages and cultures. While a single picture is important, individuals who have different roles and responsibilities within the process have different tasks they need to perform, and thus must be able to create custom views of the whole. These customizations can be achieved through filtering and support for multiple organizations. Custom views and filters must maintain the same visual language and be shareable so that they support effective communication among stakeholders about the status of the compliance process.

Organizational processes are dynamic; they evolve in response to organizational pressures and learning. Visualizations that support such processes must be malleable if they are to continue to be used as the process evolves. This requires support for customizing so that those most familiar with the changing process, typically the end users (the controllers in the case of the SOX visualization described here), can transform their visualization as the process changes.

In this paper, we have focused mainly on a specific example of a design process and the resulting system for an internal risk and compliance application. However, we believe that many aspects of both the design process that we describe and elements of the solution hold as well for a wide variety of similar application areas. In particular, there are numerous other regulations that require organizations to assess and address risks and to ensure that they are in compliance. In the United States, such areas include tax laws, equal opportunity laws, Occupational Safety and Health Administration standards, accessibility standards, environmental standards, privacy, and ensuring the physical security of people, plants, assets, and data. Although these laws, standards, and regulations differ from country to country, the basic issues of awareness, comprehension, and compliance are universal. In each case, there is a need for cooperation and collaboration, the issues are complex, and a well-designed visualization can help. In all of these areas, a great deal of change has occurred as business and the regulatory environment have co-evolved, and there is every reason to believe that change will continue. Thus, fostering an organizational culture that is conducive to competence in these areas and providing a compelling interactive and visual way to approach issues of compliance can be expected to be more effective and less confusing than simply issuing employees an ever-changing set of rules and regulations.

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SIDEBAR

We learned through our experience working with the controllers that the compliance process is continually being refined

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BODY:

ABSTRACT

Today's dashboards draw directly from data warehouses or even from multiple databases, and are far more interactive. "Organizations have become much better at creating a smooth data surface for dashboard reporting," [Mychelle Mollot] says. "The ERPs and data warehouses are much better as source transaction systems." The technology to allow users to drill down and ask a series of related questions is robust, and customers are gaining competitive advantage from it.

ABSTRACT

Decision-making in organizations is based on a complex mix of rational and intuitive thinking. One way to help make sense of enterprise data is to use a dashboard to support business performance management. Dashboards provide summary data from business intelligence (BI) systems so that CEOs, managers and employees can get an instant reading of key performance indicators for their organization's activities. A recent survey of corporate decision-makers, conducted by the Business Performance Management (BPM) Forum, indicated that only 26% of the organizations had a well-established, formal process for making decisions. Dashboards are developed from the top down to reflect the strategy of the company, says Cognos VP of market strategy and strategic communications Mychelle Mollot. Usability is a key factor in the success of dashboards, according to MicroStrategy VP of products Mark LaRow.

FULL TEXT

Decision-making in organizations is based on a complex mix of rational and intuitive thinking. Amidst abundant data, organizations find it difficult to make decisions in which they are confident. One way to help make sense of enterprise data is to use a dashboard to support business performance management.

Dashboards provide summary data from business intelligence (BI) systems so that CEOs, managers and employees can get an instant reading of key performance indicators for their organization's activities. Increasingly, the dashboards are presenting information that is updated on a daily or even real-time basis. The indicators can be in the form of speedometers, gauges, traffic lights or other graphical representations, and are often colorcoded to provide red, yellow and green alerts. Dashboards are available from essentially all of the leading BI companies, and third-party companies have developed many specialized dashboards.

A dashboard developed for Novartis (novartis.com), using business intelligence software from Cognos (cog nos.com), is a typical example of how dashboards can be used effectively. The drug manufacturer has a complex distribution network and was unable to see patterns in orders that would support decision-making. Using the Order Management Dashboard in conjunction with its AS400 order management system, Novartis staff can spot unusual order patterns early, allowing the company to adjust inventories. In addition, the summary data allows Novartis to assess how much product is still in transit and better predict potential return quantities.

Confidence level

In today's environment of abundant data, it might be assumed that data-driven decisions are the norm. However, a recent survey of corporate decision-makers, conducted by the Business Performance Management (BPM) Forum (bpmforum.org), indicated that only 26 percent of the organizations had a well-established, formal process for making decisions. In addition, only 40 percent of the respondents had a high level of confidence in their organization's current process for making decisions.

Moreover, a gap existed between the C-level executives and low- to mid-level managers. While 64 percent of the upper-level group had a high level of confidence in their organization's decision-making process, only 36 percent of the lower-level group held that opinion. One possible interpretation for the confidence gap between management levels is that the upper-level executives have access to better data; another is that they are intrinsically more confident.

Gaining insight into information

Whatever the case, there are many indications that the decision-making process in organizations could stand some improvement. Articles abound in the business media with titles such as "Why Good CIOs Make Bad Decisions," and examples of decisions that had major adverse effects on corporations are also prevalent. Despite the overall lack of confidence, only about 14 percent of the survey respondents reported turning to a technology solution, such as planning, forecasting, reporting analysis, scorecarding or dashboarding. Some poor decisions can be alleviated by the use of technology, while others cannot.

"Having an unclear corporate vision, mission or goals was identified as a leading root cause of poor decision making," says Scott Van Camp, editorial director of the BPM Forum. "It would be difficult for a technology application to overcome this type of deficiency." Nor can it directly counteract fraud and deception, although it can make such activities more transparent.

Where technology can help the most is in the analysis and presentation of data. "Many organizations are information-rich and insight-poor," says Mychelle Mollot, VP of market strategy and strategic communications at Cognos. "They have lots of databases where information is stored, but no means to get it out and used."

The value of the dashboard is not just in the summary it presents, but also in the process through which the organization travels in order to develop it. "Dashboards are developed from the top down to reflect the strategy of the company," says Mollot. In much the same way that business process management software forces companies to make their processes more explicit, business performance management solutions require thought about what is really important to measure.

Dashboards can also be set up to show summaries of data from multiple systems that are not interoperable. That is a great advantage for organizations that want to compare data across departments; they can set up a single warehouse into which the data is delivered or even draw it directly from the disparate systems. For companies that have grown through acquisition and are trying to achieve a unified view across divisions that do not have a common IT infrastructure, that ability is particularly useful.

Early versions of dashboards were called executive information systems and had a similar goal, but they were not connected to original source data. They were derived from various databases and required significant input from the IT department. In fact, they were not sustainable.

Today's dashboards draw directly from data warehouses or even from multiple databases, and are far more interactive. "Organizations have become much better at creating a smooth data surface for dashboard reporting," Mollot says. "The ERPs and data warehouses are much better as source transaction systems." The technology to allow users to drill down and ask a series of related questions is robust, and customers are gaining competitive advantage from it.

Another difference in more recent dashboards is that they can be set up to present different views depending on the user's role. "Dashboards are often designed to cascade," says Mark EaRow, VP of products at MicroStrategy (microstrategy.com). At the top level, data is rolled up to show the big picture, but depending on roles, functions and levels, other users see a smaller slice of data. Once the system is set up, the underlying data can be used to provide a concise snapshot to a wide range of recipients with varying needs.

At Corporate Express (corporate express.com), a supplier of office and computer products, MicroStrategy's BI solution allows 2,000 employees to monitor business performance at various levels. Known for its ability to deal with large databases, MicroStrategy's product operates against a 4.5-terabyte Oracle (oracle.com) data warehouse. The executive team relies on a dashboard to monitor customer buying trends and enterprise performance. At Lowes (lowes.com), MicroStrategy provides merchandising and executive dashboards.

Usability is a key factor in the success of dashboards, according to LaRow. "You should not underestimate the value of convenience and clarity." The right information needs to be in the dashboard, naturally, but the dashboard should also engage the user.

"The real power of dashboards," he adds, "is that you can take multiple sets of data and array them on a screen that leads you to want to see another set of data right next to it." For example, an HR director looking at a spike in attrition might want to check out demographics, salary, length of tenure or other factor in attempting to explain the trend. The dashboard should allow this interactivity.

Fine-tuning the interface should be deferred for a while, though. "Don't try to make the interface pixel-perfect right away," advises LaRow. "The dashboard is likely to evolve over the first four to six months, then stabilize. Spend some time on the iterations, then finalize the look." Developers can get bogged down in making the dashboard attractive, deflecting too much attention from its functionality.

Like any decision support tool, dashboards must be used wisely. Some important determinants of success that operate within a firm cannot easily be quantified, and therefore are rarely measured. Failing to incorporate those factors into the decision-making process can send an organization down the wrong path. Other forces operating outside the company, while quantifiable (such as interest rates), may not be reflected in the dashboard, even though they may exert an influence greater than any under the organization's control. But to the extent that what can be measured can be managed, dashboards offer a valuable option for helping companies cope with the data avalanche.

By Judith La mont, KMWorld senior writer

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HIGHLIGHT:
New budgeting-and-planning software offers increasingly sophisticated visual aids: dashboards and scorecards.

BODY:

When Marc Krens joined John I. Haas Inc. 12 years ago, the privately held company was hardly a font of technological sophistication. The 10 businesses that constituted Haas, the world's largest supplier of hops for brewing, all used different accounting and financial-reporting software. Worse, the programs didn't talk to one another. As for the company's inventory-management system, "the code was in German," recalls CFO Krens, "and the guy who wrote it died."

Today, Krens is busy updating the information systems of the 81-year-old company. Much of the effort is aimed squarely at strategic planning, which until recently involved an Excel spreadsheet and a homemade model that he devised. Three years ago, Krens and his team convinced senior management at $80 million (in revenues) Haas to purchase OFA, a financial-analysis program designed by Oracle Corp. More recently, the CFO has championed the deployment of an Oracle dashboard at the Washington, D.C.-based company.

When the rollout of the dashboard is finished (it is scheduled for May 2004), Haas managers and department heads will be able to track key performance indicators from a desktop portal. Krens himself plans to monitor a greatest-hits collection-metrics culled from the dashboards of other users. "Every day," he says, "managers will be able to see how they're doing on their benchmarks."

This kind of approach has big appeal for finance managers-a fact not lost on makers of applications for finance managers. Over the past year or so, several marquee business-software vendors have acquired smaller budgeting-and-planning (B&P) outfits. Geac Computer bought Comshare, Lawson Software acquired Closedloop Solutions, and Hyperion Solutions acquired Brio Software. In the process, they've picked up considerable dashboard and scoreboard capabilities. Likewise, enterprise resource planning (ERP) vendors like Oracle and SAP AG have begun to beef up the dashboard features of their enterprise offerings.

The dashboards are selling, too. According to a June survey of 100 companies conducted by AMR Research, nearly 50 percent of respondents said they will (or plan to) roll out dashboards in the coming months. John Hagerty, a vice president at AMR Research, says that overall, sales for B&P software are up about 6 percent from the same period in 2002, and dashboards are helping fuel the increase. "Forecasting is very hot right now," says Hagerty. "Most people need a forward-looking view."

For many finance managers, the view from their existing budgeting tools-usually a patchwork of Excel spreadsheets-seems more like a glance through the rearview mirror. Often, managers must piece together budgets based on extremely historical data: last year's results. And creating a strategic plan from Excel-based forecasts offered up by scores of operating units can be a real pain. "Planning is important," says Colleen Johnston, managing director and CFO of Toronto-based Scotia Capital, which recently rolled out a planning system from INEA Corp. "But the work is disproportionate [to the reward]."

Web-enabled or portal-accessed performance dashboards, now part of robust B&P applications, offer some relief. At the very least, the technology can eliminate a lot of scut work. In many cases, dashboards sit on top of data warehouses or relational databases and are powered by superfast calculating engines within B&P software. The combination, consultants note, can make reforecasting a snap.

That's a considerable accomplishment, considering that many CFOs would rather have wisdom teeth extracted with bailing twine than run a reforecast. Before deploying a B&P program and dashboard from Clarity Systems last April, for example, monthly reforecasts at Jim Beam Brands took two weeks to complete, says Don Rogers, controller at the whiskey maker. "We dreaded it," he notes. "People were pulling their hair out."

And now? "Reforecasting takes five minutes."

Worts and All
 Ironically, dashboards would have arrived on the scene much earlier if it hadn't been for, well, dashboards. In the 1980s, software providers began flogging fancy dashboard products under the highfalutin name of executive information systems. While the systems promised plenty-and looked great-they took forever to roll out, and delivered little. Rejiggering a system required a phalanx of consultants and up to a year of recoding.

Today's breed of dashboards are much easier to use and much easier to put up. Online loan broker LendingTree Inc., for example, rolled out its Hyperion-designed dashboard in a matter of months. "Most of the employees involved with the dashboard are financial folks," notes CFO and senior vice president Keith Hall. "The tech people did not put this together."

That ease of design, coupled with a generally improving data infrastructure at most corporations, has finance executives tracking all sorts of nonfinancial metrics on their dashboards. Gary Willenbrecht, manager of corporate reporting at medical-instrument maker Beckman Coulter Inc., says he uses his dashboard (from OutlookSoft Corp.) to monitor, among other things, the number of diagnostic machines the company has sold or leased to hospitals, laboratories, and the like. This installed base, he says, provides insight into future revenue streams from the company's consumables line of products. .

How? The Fullerton, California-based company's medical-diagnostic machines require reagents to test blood samples, and only reagents sold by Beckman Coulter work with the testing equipment sold by Beckman Coulter. "As you place units out there, you have a semicaptive audience," explains Willenbrecht. "If you see the installed base is growing, the consumables base is increasing."

At Haas, CFO Krens is still evaluating the metrics he wants on his dashboard. He'll probably include standard gauges like revenues (actual, historical, and budget), cash flow, and receivables. But given the unique nature of the hops business, it's fair to say that Krens's dashboard will feature some oddball items as well.

For example, Krens notes that some brewers place their orders for hops in January and February, although most hops aren't harvested until the fall (hops serve double duty, protecting beer and adding flavor and aroma). Hence, it's crucial for Haas to know how much product the company will have available to fill orders-not exactly a slam dunk when you're talking about a crop.

To get a handle on crop yield, Haas maintains an agronomy department in the Yakima Valley in Washington State, and the company operates a production facility for each of its three 1,000-acre farms in Washington and Oregon. The department tracks temperature and rainfall information, predicts harvests based on past weather/yield patterns, and conducts testing of growth on the vines.

The crop report, along with metrics taken from the dashboards of managers in other departments such as human resources and sales, will probably end up on Krens's dashboard. "The department heads know their business better than I do, so they're developing their own metrics," he notes. "I'll glean one or two from each to get a full view of the company."

Red Light, Green Light
 The view on many B&P dashboards can be color-coded, to help users spot variances and avoid nasty surprises. On LendingTree's "Packer chart," for example, a 5 percent or better favorable variance to budget is green, says Hall, while a 5 percent or worse unfavorable variance is yellow.

Most dashboards feature a traffic-light setup, with a red signal flagging sizable negative deviations. That sort of eye-grabbing visibility can cause problems, however. "If a certain business sector is having a bad quarter, you can end up with too much red on the screen," notes Beckman Coulter's Willenbrecht. That can stir up hard feelings among employees. "Some people say it's too distracting," he adds.

Indeed, some users say the technology can be overwhelming at times. Not surprisingly, vendors that tout dashboards and B&P software as part of a corporate performance-management suite tend to trumpet the full-and we mean full-capabilities of their products. In some cases, screens contain 20 or more charts, graphs, and visuals. "The [vendor's] argument," says Lee Geishecker, research vice president at consultancy Gartner, "is, 'Your business is complicated, and our software gives you everything you need.'"

Sometimes, more than you need. Progress Rail, an Albertville, Alabama-based railroad services and products specialist (2002 revenues: $900 million), recently deployed a dashboard product from SAS. CFO David Klementz says the company's management is pleased with the product so far. In fact, he says the next phase of the rollout will involve adding a greater degree of "resolution" (granularity) to the information presented on screen. But, Klementz cautions, it's crucial to balance resolution with perspective. It's important to keep the data useful, he explains, but users could end up with a system that's impossible to manage if there are too many metrics being tracked.

Finance executives know exactly what Klementz is talking about. They're also pretty familiar with long, costly rollouts of software. Mark Dani, financial systems analyst at Accelrys Inc., says the San Diego-based scientific-software maker recently decided to move from Excel-based budgeting to an enterprisewide approach-a big step up. But, he says, officers wanted an application that would be readily picked up by employees. They settled on Active Planner, a program marketed by Best Software Inc. "It has an Excel-ish look," notes Dani. "We wanted the learning curve to be minimal."

That appears to top the wish list for many shoppers of dashboards and B&P offerings. Controller Rogers says that when Jim Beam's managers began shopping for a B&P product, they looked at an extremely powerful offering from a well-known business-intelligence (BI) vendor. But they decided not to buy it. How come? "You need Jedi [knights] to run the stuff," claims Rogers.

What's Wrong with Quicken?
 Ultimately, Jim Beam purchased a B&P program from Clarity Systems. The application cost $50,000, compared with $250,000 for the app from the spurned BI vendor. Initially, the dramatic price difference was a cause of concern for Jim Beam's management. "The [Clarity] software was so cheap," says Rogers, "we wondered if we were buying Quicken to close our books."

In reality, the wildly varying prices probably say more about marketing strategies than software. Most ERP vendors, for instance, don't sell B&P apps (or performance dashboards) separately. Rather, they market the programs as modules within larger, enterprisewide packages. The vendors stick to enterprise pricing as well: dashboard deployments with those software makers can run as high as $500,000.

Niche players offer more-reasonable prices, often below $250,000. In fact, according to an AMR Research study of dashboard rollouts, 37 percent of respondents said they had budgeted less than $100,000 for their dashboard and scorecard projects.

But shoppers who have come to expect serious discounting from software vendors may be in for a bit of a surprise when dealing with B&P outfits. Unlike customer relationship management software, planning apps are in demand right now. "[B&P] vendors are not that hungry," says AMR Research's Hagerty. "There's some ability to negotiate, but the vendors are not giving it away."

On the other hand, high sticker prices might have a silver lining-if, that is, they prod buyers to make better plans for buying planning software.

John Goff is technology editor of CFO.

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HEADLINE: EVERYBODY'S SYSTEM -- Executive information systems are no longer reserved for the corporate elite

BYLINE: Scott Wallace

BODY:

'The meaning of EIS," quips Cliff Conneighton, an analyst at the Gartner Group Inc., "is changing from 'executive information system' to 'everybody's information system.' "

Historically, executive information systems have offered a carefully crafted view from the executive suite into the repository of corporate data-familiarly known as the "glass house." But with data and processing migrating from the mainframe to the desktop, looking at centralized information often provides only part of the picture. Moreover, as organizations decentralize, workers further down the organizational chart need access to the fast-changing, user-focusable perspectives that an EIS can offer. The result is that old-style, centralized executive information systems are evolving into-or competing with-more distributed desktop systems.

While cheap desktop MIPS (millions of instructions per second) and robust local area networks are often part of an EIS, workstations and networks are widely viewed as expediting, rather than enabling, the deployment of the executive system. "The trend is to take advantage of the fact that users already have familiarity with some PC tools," says Conneighton, program director for office information systems at the Stamford, Conn., consultancy. "In addition, more and more of the important data is no longer just the transactional data off the financial system. It's likely to be application data found on the LAN, on a departmental file server, or in somebody's spreadsheet," he points out.

Exactly what an EIS is has always been somewhat elusive, observes Claire Gillan, manager of application solutions for International Data Corp. in Framingham, Mass. "When EISs started to take off, the distinction between decision support systems and executive information systems was that a DSS was more of an interactive, analytically intensive tool, while an EIS focused more on summarizing critical data, offering someone who was not a computer 'power user' an easy way to look at data," says Gillan.

As hardware and software technologies have evolved, end users have come to expect an EIS to deliver both a user-friendly interface and access to analytical routines that turn data into information and then support tracing that information back to its source data.

One such EIS application is in use at Heidelberg Harris USA, a $300 million manufacturer of sheet-fed printing presses in Dover, N.H. Tom Fontaine, VP of IS, explains how Harris came to build its distributed, PC-based suite of applications, known internally as the "Financial Dashboard." This set of applications replaced the "Blue Book," a financial "planned-versus-actual" report that didn't come out until the 15th of each month, says Fontaine. The Blue

Book also required a lot of time to read and interpret. "Now, depending upon how they set up their view, managers can be as current as the last order processed through accounts payable," he says.

The Financial Dashboard collects data-some of it in real time from manufacturing stations-to assemble information and present a view of Harris's operations. That's quite a feat, given that operations span a 700-node wide area network with sites in Durham and Dover, N.H.; Nashville, Tenn.; Westerly, R.I.; and Fort Worth, Texas, in addition to offices in Mexico, France, and Germany.

Despite its name, the EIS at Harris is not reserved for upper-level managers alone. "Senior management didn't want to see pie charts unless they felt comfortable that the underlying data was good; they wanted the operating management to review it. We were almost forced into moving [the EIS] down the organizational chart," recounts Fontaine. "Now, at the highest levels, they're seeing very summary-level information. But they know they can bore down through that and get to the real data."

The consistent user interface the EIS provides is one of its major benefits, says Fontaine. "Financial Dashboard was just a forerunner of downsizing most of our applications," Fontaine explains. "Every time I changed from a mainframe-based application to a PC-based application, I had to change all the reporting mechanisms. This way, I can give my users a constant interface. Even though I'm changing the world, it's transparent to them; everything looks the same."

ON BOARD THE ENTERPRISE

User interface consistency is a hallmark of Pratt & Whitney's Enterprise Support System (ESS). East Hartford, Conn.-based Pratt & Whitney, a division of United Technologies Corp., manufactures jet engines for commercial and military aircraft. The company's ESS is based upon Commander, an EIS from Comshare Inc. in Ann Arbor, Mich.

"Traditional systems that service an organization's information needs require a tremendous commitment to training," says Walter Dempsey, manager of ESS development in the business management and planning department. "Those systems are impregnated into departments based on functions, and when you switch to another function, you have no idea how to get information. You've got to be trained all over again."

But Dempsey says Pratt & Whitney's ESS will change all that. "We'll see many more systems with EIS front-ends because they're intuitive," he says. "A very intuitive user interface eliminates the training process. It eliminates the tremendous time lag to bring useful information back to the business. And it's the biggest productivity enhancement you can find."

Like Harris, Pratt & Whitney is making the transition from a mainframe-based, centralized environment to a networked, desktop one. But that move is not essential to successfully implementing the company's ESS. "EIS is technology transparent," Dempsey contends. "Some people say, 'If I don't have a data infrastructure in place, I can't proceed with an EIS.' But that's not true. You'll never have the data infrastructure in place because the business is always changing."

Pratt & Whitney's ESS is the company's most serious effort to date to distribute the right information to everyone that needs it, says Dempsey. That information concerns insights into operations that are continually in a process of flux. "We're not talking about data that exists; we're talking about brand new data that we have to go out and collect," says Dempsey.

In an ever-changing business environment, one thing remains constant: The customer comes first. Pratt & Whitney's customers have have one fundamental need: to keep their planes in flight. "The real sin in our business is an aircraft on the ground; it results in a direct loss of revenue to our customers," explains Dempsey. How does the ESS help with customer service? The system is designed to not only ensure that adequate spare parts are available whenever and wherever needed, says Dempsey, but also to monitor management of the company's engines in the field, to assess engineering and R&D investments, and to understand how customer support representatives can improve product reliability.

Because the ESS cuts across departmental boundaries, development does not take place in traditional ways. "It's not the old development technology or mentality," maintains Dempsey. "At Pratt and Whitney, it involves a partnering between MIS and the business units. We'll talk about what the needs are, but it's no longer the needs of marketing or of product support, it's the whole business."

DISTRIBUTED DATA

At Tropicana Products Inc. in Bradenton, Fla., manager of sales planning Steve Goodfriend is upgrading the company's 13-year-old sales information system to an EIS from Effem Services Inc. of Mount Olive, N.J. "One of the key changes we've made is that the system is no longer a 'headquarters only' tool: we've distributed the information out to our regional offices throughout the United States," says Goodfriend.

Corporate executives use their X-terminals to access Tropicana's EIS and take advantage of its graphical capabilities. Regional and traveling managers dial-in for a character-based version of the system's suite of pre-defined reports and views. But the system not only provides more comprehensive and timely information, it has also caused some fundamental organizational changes. "There's been a lot more teamwork between sales and MIS. The EIS is not just a sales system nor is it just an MIS system," says Goodfriend.

Harry Grossman, director of management science at Citicorp's U.S. Card Products Group in Hagerstown, Md., also says his EIS has altered some fundamental business processes at his company. Based on a system from Pilot Executive Software in Boston, Grossman's EIS tracks operational statistics of Citicorp's customer service telephone representatives. "Our Automatic Call Distributors [ACD] consist of two components: one that distributes calls to the agents and monitors the call flow and one that generates statistics on that flow," says Grossman. "The ACD normally generates lots of paper reports. We went into the ACD and wrote some code that electronically transfers those reports to our EIS every half-hour."

The raw data on employee performance is structured into a series of views that provide both summary and detailed data on productivity, availability, and work quality. "We recognized as we were building the system that we were providing good information to senior executives. But the real solutions to problems rested not with the senior executives but with several levels of management down-with the line managers who were really responsible for achieving our productivity goals," Grossman says. "The system will allow us to identify who our top performers are and to implement a fact-based, pay-per-performance system."

United HealthCare Corp. in Minnetonka, Minn., offers a variety of management and specialty services to health-care providers. The company uses its Comshare EIS, workstations, and communication linkages to provide health plan managers, employee benefit managers, and pharmacy managers with performance and cost information. "The system helps them better manage their costs and utilization of services," says Rochelle Wooley, director of managed care reporting systems.

United HealthCare's EIS is unusual in that access to it is provided on a fee basis to its customers. "It's a wonderful marketing tool for the health plans to help their customers understand the kinds of services their employees are receiving," Wooley says. "If, for instance, there is a high incidence of back pain for a particular employer group, the plan can work with that group to put together health education programs."

At Xerox Canada Inc. in Ontario, a Comshare-based EIS system is providing executives with automatically updated information on service activities. "We have about 1,700 sales reps in Canada; we track how many calls they're getting on a day-by-day basis, how many calls they're able to complete, and how many customers' problems haven't been resolved," says Sheilah Reid, manager of decision support system for the company's IS division.

Another major change is that the system forces a commonality of perspective and definition across the entire company. "It's no longer possible to be in a management committee meeting and have somebody present their numbers followed by somebody else with totally different numbers on the same topic," says Reid. "We have concurrence on terminology that moves us away from private ownership of data; now it's on the executive system."

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ed, -head•ing, -heads. — *tr.* 1. To pilot or drive (a vehicle) carrying no passengers or freight. 2. To pull (dead or dying blossoms) off a flower. — *adv.* Without passengers or freight.

dead heat *n. Sports.* A race in which two or more contestants compete evenly or finish at the same time.

dead letter *n.* 1. An unclaimed or undelivered letter that after a time is destroyed or returned to the sender by the postal service. 2. A law, directive, or factor formally in effect but no longer valid or enforced.

dead lift *n. Sports.* A weightlifting event in which the weight is lifted from the floor to the level of the hips and then lowered by controlled effort to the floor.

dead•light (dĕd′lït′) *n.* 1. *Naut.* a. A strong shutter fastened over a porthole in stormy weather. b. A thick window in a ship's side or deck. 2. A skylight that cannot be opened.

dead•line (dĕd′lïn′) *n.* 1. A time limit, as for payment of a debt. 2. A line in a prison that prisoners can cross only at the risk of being shot. — *tr.v.* **-lined, -lin•ing, -lines.** To govern by setting a time limit.

dead load *n.* The fixed weight of a structure or piece of equipment, such as a bridge on its supports.

dead•lock (dĕd′lŏk′) *n.* A standstill resulting from the opposition of two unrelenting forces. — *tr. & intr.v.* **-locked, -lock•ing, -locks.** To bring or come to a standstill.

dead•ly (dĕd′lē) *adj.* **-li•er, -li•est.** 1. Causing or tending to cause death. 2. Suggestive of death. 3. Wanting to kill; implacable. 4.a. Destructive in effect: *a deadly critique.* b. Tending to take away vitality, effectiveness, or force. 5. Absolute; utter: *deadly concentration.* 6. Extreme or terrible. 7. Extremely accurate; unerring. 8. Dull, tedious, and boring. — *adv.* 1. So as to suggest death. 2. To an extreme. — **dead′li•ness** *n.*

deadly nightshade *n.* 1. See **belladonna** 1. 2. See **bittersweet nightshade.**

deadly sin *n.* One of the seven sins — anger, covetousness, envy, gluttony, lust, pride, and sloth — that are regarded as fatal to one's soul.

James Dean

dead-man's float (dĕd′mănz′) *n. Sports.* A prone floating position in which the swimmer's arms are extended straight forward above the head and the legs are held together.

dead march *n. Mus.* A slow, solemn funeral march.

dead nettle *n.* Any of several weedy plants of the genus *Lamium,* having clusters of small, usu. purplish flowers.

dead-on (dĕd′ŏn′, -ôn′) *adj. Informal.* Precisely accurate and to the point.

dead•pan (dĕd′păn′) *n.* 1. An expressionless face. 2. A person, esp. a performer, who has or assumes a blank expression. — *adj.* Impassively matter-of-fact, as in style or expression: *deadpan humor.* — *adv.* With a deadpan face. — *tr. & intr.v.* **-panned, -pan•ning, -pans.** To express or express oneself in a deadpan way.

dead point *n.* See **dead center.**

dead reckoning *n.* 1. A method of estimating the position of an aircraft or a ship without astronomical observations, as by applying to a known position the course and distance traveled since. 2. Prediction based on inference; guesswork. [Poss. alteration of *ded.,* abbr. of *deduced* < *deduce,* to trace from the beginning. See DEDUCE.]

Dead Sea (dĕd). A salt lake, c. 397 m (1,300 ft) below sea level, between Israel and Jordan; the lowest point on the earth.

dead weight *n.* 1. The weight of a heavy motionless mass. 2. An oppressive burden or difficulty. 3. See **dead load.**

dead•wood (dĕd′wo͝od′) *n.* 1. Dead branches or wood on a tree. 2. One that is burdensome or superfluous. 3. *Naut.* The vertical planking between the keel of a vessel and the sternpost.

deaf (dĕf) *adj.* **deaf•er, deaf•est.** 1. Partially or completely lacking in the sense of hearing. 2. **Deaf.** Of or relating to the Deaf or their culture. 3. Refusing to listen. — *n.* 1. Deaf people considered as a group. 2. **Deaf.** The community of deaf people who use American Sign Language. [ME *def, deef* < OE *dēaf.*] — **deaf′ly** *adv.* — **deaf′ness** *n.*

Usage Note: Some writers have lately introduced a distinction between the lowercase noun *deaf,* which is used to refer simply to people with extensive hearing disorders, and the capitalized noun *Deaf,* which refers to the community that uses American Sign Language as a primary means of communication.

deaf•en (dĕf′ən) *v.* **-ened, -en•ing, -ens.** — *tr.* 1. To make deaf, esp. momentarily by a loud noise. 2. To make soundproof. — *intr.* To cause deafness. — **deaf′en•ing•ly** *adv.*

deaf-mute also **deaf mute** (dĕf′myo͞ot′) *Offensive.* — *n.* A person who can neither hear nor speak. — *adj.* (dĕf-myo͞ot′). Unable to speak or hear.

deal¹ (dēl) *v.* **dealt** (dĕlt), **deal•ing, deals.** — *tr.* 1. To give out as a share or portion; apportion. 2. To distribute among several recipients. See Syns at **distribute.** 3. To sell: *deal cocaine.* 4. To administer; deliver: *dealt him a blow.* 5. *Games.* a. To distribute (playing cards) among players. b. To give (a specific card) to a player while so distributing. — *intr.* 1. To be occupied; treat: *deals with the Middle Ages.* 2. To behave in a specified way toward another or others; have transactions: *deals honestly with me.* 3. To take action with respect to someone or something: *dealing with complaints.* See Syns at **treat.** 4. To do business; trade: *dealing in diamonds.* 5. *Games.* To distribute playing cards. — *n.* 1. The act or round of apportioning or distributing. 2. *Games.* a. Distribution of playing cards. b. The cards so distributed; a hand. c. The right or turn of a player to distribute the cards. 3. An indefinite quantity or degree. 4. An agreement often arranged secretly, as in politics. 5.a. A business transaction. b. An agreement, esp. one that is mutually beneficial. 6. *Informal.* A sale favorable esp. to the buyer; a bargain. 7. *Informal.* Treatment received: *a raw deal.* [ME *delen* < OE *dǣlan,* to divide, share. See **dail-*.**]

deal² (dēl) *n.* 1. A fir or pine board cut to standard dimensions. 2. Fir or pine wood. [ME *dele* < MDu. and MLGer. *dele,* plank.]

de•a•late (dē-ā′lāt′) or **de•a•lat•ed** (-lā′tĭd) — *adj.* Having lost the wings. Used of insects that shed their wings after mating flight. — *n.* A dealate insect. — **de′a•la′tion** *n.*

deal•er (dē′lər) *n.* 1. One engaged in buying and selling: *drug dealer.* 2. *Games.* The one who distributes cards.

deal•er•ship (dē′lər-shĭp′) *n.* A franchise to sell specific items in a certain area.

deal•fish (dēl′fĭsh′) *n., pl.* **dealfish** or **-fish•es.** An Atlantic ribbonfish *(Trachipterus arcticus)* having a compressed, tapering silvery body. [< DEAL².]

deal•ing (dē′lĭng) *n.* 1. **dealings.** Transactions or relations with others, usu. in business. 2. Method or manner of conduct in relation to others; treatment: *honest dealing.*

de•am•i•nate (dē-ăm′ə-nāt′) *tr.v.* **-nat•ed, -nat•ing, -nates.** To remove an amino group, NH_2, from (an organic compound). — **de•am′i•na′tion** *n.*

de•am•i•nize (dē-ăm′ə-nīz′) *tr.v.* **-nized, -niz•ing, -niz•es.** To deaminate. — **de•am′i•ni•za′tion** (-nĭ-zā′shən) *n.*

dean (dēn) *n.* 1.a. An administrative officer in charge of a college, faculty, or division in a university. b. An officer of a college or high school who counsels students and supervises the enforcement of rules. 2. *Eccles.* The head of the chapter of canons governing a cathedral or collegiate church. 3. *Rom. Cath. Ch.* A priest appointed to oversee a group of parishes within a diocese. 4. The senior member of a body or group. [ME *deen* < OFr. *deien* < LLat. *decānus,* chief of ten < Gk. *dekanos* < *deka,* ten. See **dekm̥*.**] — **dean′ship′** *n.*

Dean (dēn), **James Byron.** 1931–55. Amer. actor whose films include *East of Eden* and *Rebel Without a Cause* (both 1955).

Deane (dēn), **Silas.** 1737–89. Amer. diplomat who persuaded France to supply aid to the Revolutionary cause.

dean•er•y (dē′nə-rē) *n., pl.* **-ies.** The office, jurisdiction, or official residence of an ecclesiastical dean.

dean's list (dēnz) *n., pl.* **deans' lists.** A list of students, esp. in a college, who have attained high academic rank.

dear¹ (dîr) *adj.* **dear•er, dear•est.** 1.a. Loved and cherished: *my dearest friend.* b. Greatly valued; precious: *lost everything dear to them.* 2. Highly esteemed or regarded. Used in direct address, esp. in salutations. 3.a. High-priced; expensive. b. Charging high prices. 4. Earnest; ardent. 5. *Obsolete.* Noble; worthy. — *n.* 1. One that is greatly loved. 2. An endearing, lovable, or kind person. — *adv.* 1. With fondness; affectionately. 2. At a high cost: *sold their wares dear.* — *interj.* Used as a polite exclamation, chiefly of surprise or distress. [ME *dere* < OE *dēore.*] — **dear′ly** *adv.* — **dear′ness** *n.*

dear² (dîr) *adj.* Severe; grievous. [ME *dere* < OE *dēor.*]

Dear•born (dîr′bôrn′, -bərn). A city of SE MI W of Detroit. Pop. 89,286.

Dearborn, Henry. 1751–1829. Amer. soldier and politician who fought in the American Revolution.

Dearborn Heights. A city of SE MI, a suburb of Detroit. Pop. 60,838.

Dear John (dîr) *n.* A letter, as to a serviceman, requesting a divorce or ending a personal relationship.

dearth (dûrth) *n.* 1. A scarce supply; a lack. 2. Shortage of food; famine. [ME *derthe* < OE **dēorthu,* costliness < *dēore,* costly. See DEAR¹.]

death (dĕth) *n.* 1. The act of dying; termination of life. 2. The state of being dead. 3. The cause of dying. 4. A manner of dying: *a heroine's death.* 5. Often **Death.** A personification of the destroyer of life, usu. represented as a skeleton holding a scythe. 6.a. Bloodshed; murder. b. Execution. 7. *Law.* Civil death. 8. The termination or extinction of something. — *idioms.* **at death's door.** Near to death; gravely ill or injured. **be the death of (someone).** To distress or irritate (someone) to an intolerable degree. **put to death.** To execute. **to death.** To an intolerable degree; extremely. [ME *deth* < OE *dēath.* See **dheu-²*.**]

death angel *n. Bot.* See **death cup.**

death•bed (dĕth′bĕd′) *n.* 1. The bed on which a person dies. 2. The last hours before death.

death benefit *n.* Insurance money payable to a deceased person's stipulated beneficiary.

death•blow (dĕth′blō′) *n.* 1. A stroke or blow that causes death. 2. A destructive event or occurrence.

death camas also **death camass** *n.* Any of several plants of the genus *Zigadenus* of western North Ame[rica] ... of greenish flowers and are poisonous ...

death cup *n.* A poisonous, usu. white ... *phalloides)* having a prominent cup-sh[aped] ...

death duty *n. Chiefly British.* A tax on ... inheritance tax.

death house *n.* See **death row.**

death instinct *n. Psychiat.* 1. A primitiv[e] ... tion, decay, and death, manifested by ... pleasure, postulated by Sigmund Freud a[s] ... opposing the life instinct. 2. Death wis[h] ...

death•less (dĕth′lĭs) *adj.* Not subject to ... immortal. — **death′less•ly** *adv.* — **dea[th]** ...

death•ly (dĕth′lē) *adj.* 1. Of, resembling ... death: *a deathly silence.* 2. Causing deat[h] ... the manner of death. 2. Extremely; ver[y] ...

death mask *n.* A cast of a person's face ...

death penalty *n.* A sentence of punishm[ent] ...

death rate *n.* The ratio of total deaths t[o] ... a specified community or area over a spe[cified] ...

death rattle *n.* A gurgling or rattling soun[d] ... the throat of a dying person, caused ... through mucus.

death row (rō) *n.* The part of a prison for ... have received the death penalty.

death's-head (dĕths′hĕd′) *n.* The human ... mortality or death.

deaths•man (dĕths′mən) *n. Archaic.* An ...

death tax *n.* 1. See **inheritance tax.** 2. S[ee] ...

death•trap (dĕth′trăp′) *n.* 1. An unsaf[e] ... structure. 2. A perilous circumstance or ...

Death Valley. An arid desert basin of E C[A] ...

death warrant *n.* 1. *Law.* An official orde[r] ... son's execution. 2. Something that destro[ys] ... tion; a deathblow.

death•watch (dĕth′wŏch′) *n.* 1. A vigil ke[pt] ... dead person. 2. One who guards a conde[mned] ... execution. 3. A deathwatch beetle.

deathwatch beetle *n.* Any of several woo[d] ... of the family Anobiidae, esp. *Xestobium r*... head makes a clicking sound that was supe[rstitiously] ... as a portent of death.

death wish *n.* 1. *Psychiat.* A desire for sel[f] ... accompanied by feelings of depression, ho[pelessness] ... reproach. 2. The desire for the death of ... ward whom one has unconscious hostility ...

Deau•ville (dō′vĭl, dō-vēl′). A resort city of ... English Channel. Pop. 4,682.

deb (dĕb) *n. Informal.* A debutante.

deb. *abbr.* Debenture.

de•ba•cle (dĭ-bä′kəl, -băk′əl) *n.* 1. A sudd[en] ... fall, or defeat; a rout. 2. A total, often ... 3. The breaking up of ice in a river. 4. A ... *débâcle* < *débâcler,* to unbar < OFr. *desb*... *bacler,* to bar, ult. < Lat. *baculum,* rod. S[ee] ...

De Ba•key (də bā′kē), **Michael Ellis.** b. 19[08] ... who implanted the first totally artificial ... being (1966).

de•bar (dē-bär′) *tr.v.* **-barred, -bar•ring, -b**... or shut out; bar. 2. To forbid, hinder, or ... *barren* < OFr. *desbarer,* to unbar : *des-,* d[e-] ... (< *barre,* bar; see BAR¹).] — **de•bar′ment** ...

de•bark (dĭ-bärk′) *v.* **-barked, -bark•ing, -b**... load, as from a ship or an airplane. — *intr.* ... *débarquer* : *dé-,* from (< OFr. *de-;* see DE-) ... (< OFr.; see BARK³).] — **de′bar•ka′tion** (d[ē]) ...

de•base (dĭ-bās′) *tr.v.* **-based, -bas•ing, -ba**... character, quality, or value; degrade. See ... [DE- + BASE².] — **de•base′ment** *n.* — **de•**...

de•bat•a•ble (dĭ-bā′tə-bəl) *adj.* 1. That can ... cussed. 2. Open to dispute. — **de•bat′a•bl**...

de•bate (dĭ-bāt′) *v.* **-bat•ed, -bat•ing, -bat**... consider something; deliberate. 2. To engag[e] ... discussing opposing points. 3. To engage in ... sion or argument. 4. *Obsolete.* To fight ... 1. To deliberate on; consider. 2. To dispute ... 3. To discuss or argue (a question, for ex[ample]) ... 4. *Obsolete.* To fight or argue for or over. ... sion involving opposing points; an argument. ... consideration. 3. A formal contest of argume[ntation] ... two opposing teams defend and attack a gi[ven] ... 4. *Obsolete.* Conflict; strife. [ME *debaten* < ... *de-,* de- + *battre,* to beat; see BATTER¹.] — d... — **de•bat′er** *n.*

de•bauch (dĭ-bôch′) *v.* **-bauched, -bauch•i**... — *tr.* 1.a. To corrupt morally. b. To lead a[way] ... lence or virtue. 2. To reduce the value or qu[ality] ... 3. *Archaic.* To cause to forsake allegiance. — ... in dissipation. — *n.* 1. The act or a period ... 2. An orgy. [Fr. *débaucher* < OFr. *desbauchie*[r] ... rough-hew timber : *des-,* de- + *bauch,* beam ... — **de•bauch′ed•ly** (-bô′chĭd-lē) *adv.* — **de•**...

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called also respectively (1) *transmission deafness, conduction deafness,* or *conductive deafness,* (2) *perceptive deafness* or *nerve deafness,* and (3) *central deafness, cortical deafness,* or *psychic deafness*

deaf nettle *n* : a dead nettle (*Lamium purpureum*)

deaf nut *n* **1** : a nut with no kernel **2** : a thing without profit

de-air \(ˈ)dē+\ *vt* [*de-* + *air* (n.)] : to remove air from (wet clay) by pugging under vacuum thereby increasing wet strength and density

[1]**deal** \ˈdēl, *esp before pause or consonant* -ēəl\ *n* -s [ME *deel, del,* fr. OE *dǣl;* akin to OE *dāl* division, portion, OHG *teil* part, ON *deild* share, Goth *dails* part] **1** *obs* : PART, PORTION, SHARE **2** : an indefinite quantity, degree, or extent ⟨it makes a good ~ of difference⟩ ⟨it means a great ~ to him⟩ ⟨he hasn't got a great ~ of money⟩ **3 a** : the act, process, or method of distributing cards to players in a card game **b** : the privilege or duty of acting as dealer ⟨it's my ~⟩ **c** : a period in the play of a card game embracing all phases from the shuffle through the determination or scoring of the result — compare HAND 10a(4) **4** : a large quantity : LOT ⟨a ~ of years —Raymond Moley⟩

[2]**deal** \"\ *vb* **dealt** \ˈdelt\ **dealt** \"\ **dealing** \ˈdēliŋ\ **deals** \ˈdē(ə)lz\ [ME *delen,* fr. OE *dǣlan;* akin to OHG *teilen* to divide, ON *deila,* Goth *dailjan;* denominative fr. the root of E [1]*deal*] *vt* **1** *obs* : DIVIDE, SEPARATE, SEVER **2 a** : to give as one's share or portion : DISTRIBUTE, APPORTION, METE ⟨*dealt* justice to all men⟩ — usu. used with *out* ⟨*dealt* out three sandwiches apiece⟩ **b** (1) : to distribute (one or more playing cards) to a player or the players in a card game (2) : to distribute the cards for (a specified card game) ⟨~ poker⟩ (3) : to act as dealer in (a specified game) ⟨~ craps⟩ **3** : ADMINISTER, DELIVER, BESTOW ⟨~ the boy a scolding⟩ ~ *vi* **1** *obs* : to be a sharer : SHARE **2 a** : to distribute the cards in a card game **b** : to have the function or duty of distributing cards to the players in a card game **c** : to act as a dealer in a gambling game **3 a** : to have to do : concern oneself : TREAT — used with *with* ⟨the book ~s with all aspects of the subject⟩ **b** : to become occupied or busy — used with *in* ⟨~*ing* in matters of no concern to him⟩ ⟨fond of ~*ing* in large generalities⟩ **4** : to act toward a person or regarding a thing : DO — used with *by* or *with* ⟨return . . . and I will ~ well with thee —Gen 32:9 (AV)⟩ **5** *archaic* : to have dealings — used with *with* ⟨~*ing* with witches —Shak.⟩ **6** *archaic* : to act as intermediary : make arrangements : NEGOTIATE — used with *with* or *between* **7** : to do a retailing or distributing business : TRADE, TRAFFIC — used with *in* before a thing ⟨he ~s in flour⟩ and with *with* before a person ⟨he ~s fairly with all his customers⟩ **8** *obs* : CONTEND, STRUGGLE, QUARREL — used with *with* **9** : to take action (as in regard to some object, problem, or source of difficulty) : come to grips — used with *with* ⟨he may ~ as he pleases with his own property⟩ ⟨had to ~ with a catastrophic inflation⟩ ⟨*dealt* with his problems as they arose⟩ ⟨*dealt* harshly with the rebels⟩ **syn** see DISTRIBUTE, TREAT

[3]**deal** \"\ *n* -s **1** *obs* : DEALINGS, INTERCOURSE **2 a** : an act of buying and selling : an offering of a combination of products at a special price ⟨a package ~⟩ : a reciprocal arrangement or agreement : BARGAIN **b** : treatment received in a transaction from another ⟨a raw ~⟩ or from impersonal forces or circumstances ⟨a rough ~⟩ **c** *usu cap* : a particular policy of national administration esp. of economic or politico-economic affairs ⟨Theodore Roosevelt's Square *Deal*⟩ ⟨the New *Deal*⟩ ⟨the Fair *Deal*⟩ **3** : an often clandestine arrangement to gain mutual advantage for those interested : a negotiated settlement of an issue (as a lawsuit) ⟨law . . . has a way of beginning with ideals and ending with ~s —H.A.Overstreet⟩

[4]**deal** \"\ *n* -s [MD or MLG *dele* plank; akin to OHG *dili, dilla* plank, plank floor — more at THILL] **1 a** *Brit* : a board of fir or pine cut to any of several specified sizes — see DEAL END, SLIT DEAL, STANDARD DEAL, WHOLE DEAL **b** *in the U.S. export trade* : sawed yellow-pine lumber nine inches and wider and three, four, or five inches thick **2** : pine or fir wood : deals in the aggregate ⟨a floor of ~⟩

[5]**deal** \"\ *adj* : made of deal; *broadly* : made of plain unfinished wood ⟨a ~ table⟩

deal apple *n* [[4]*deal*] : the cone of the white pine or of the fir

de-alate \dēˈā,lāt, -ˌlət\ *n* -s [*de-* + *alate*] : a dealated insect : a mature sexual individual of a kind of insect that undergoes dealation

de-alat-ed \-ˌlād-əd\ *adj* [*de-* + *alated*] : divested of the wings — used of postnuptial adults of certain insects (as ants and termites) that drop their wings after a nuptial flight — **de-ala-tion** \(ˌ)dē,āˈlāshən\ *n* -s

de-al-bate \dēˈal,bāt, -ˈōl-\ *adj* [L *dealbatus,* past part. of *dealbare* to whitewash — more at DAUB] *bot* : covered with an opaque white powder

deal board *n* [[4]*deal*] : a fir or pine board : DEAL

deal end *n* [[4]*deal*] : a deal board less than six feet long — usu. used in pl.

deal-er \ˈdēlə(r)\ *n* -s [ME *delere,* fr. OE *dǣlere,* fr. *dǣlen* to divide + *-ere* -er — more at DEAL] **1** : one that divides, distributes, or delivers **2** *obs* : NEGOTIATOR, AGENT, GO-BETWEEN **3** : one that acts or conducts himself in some specified way toward others ⟨noted as a plain ~⟩ **4** : one that does business : TRADER, TRAFFICKER, MIDDLEMAN : a person who makes a business of buying and selling goods esp. without altering their condition ⟨a ~ in dry goods⟩ ⟨~ in stocks⟩ ⟨an automobile ~⟩ — compare MANUFACTURER **5** : one that buys and sells (as securities, commercial paper, or foreign exchange) on his own account — compare BROKER 1b **6 a** *Brit* : STOCKJOBBER a — distinguished from *broker* **b** : a member of a stock exchange who buys and sells as principal rather than as agent for a customer **7 a** (1) : a person who deals cards (2) : a machine or device for dealing cards **b** (1) : a gambler or employee of a gambling house who officiates at a game or gaming table (as a stickman, tourneur, croupier, or cashier) (2) : the chief among such persons : the person in charge of the table (as the stickman in craps or the tourneur at roulette)

dealer acceptance *n* : purchase by a retail merchant because of a known demand

dealer help *n* : promotional aid (as samples, counter or window displays, briefings for clerks) that is furnished retailers by manufacturers and wholesalers to stimulate sales of advertised products or to gain retailers' goodwill and continued patronage

dealer's choice *n* : a card game (as poker) in which the dealer may designate the variant to be played and set the stakes

deal-er-ship \-ˌship\ *n* -s : an authorized sales agency : the business of a distributor ⟨an automobile ~⟩ ⟨a ~ for planes⟩

dealfish \ˈ-ˌ-\ *n* [[4]*deal* + *fish*] : any of several long thin fishes of the genus *Trachypterus* inhabiting the deep sea — called also *ribbonfish*

deal frame *n* [[4]*deal*] : LOG FRAME

deal in *vt* : to include (a specified player) among those to whom cards are dealt ⟨*deal* me *in*⟩

dealing *n* -s [ME *deling,* fr. gerund of *delen* to deal] **1** : INTERCOURSE, TRAFFIC — usu. used in pl. ⟨~*s* with the devil⟩ **2** : method of business or manner of conduct ⟨underhand ~⟩

dealing box *n* : BOX 13

de-alkalization \(ˌ)dē+\ *n* -s : the process of dealkalizing

de-alkalize \(ˈ)dē+\ *vt* [*de-* + *alkalize*] : to remove alkali from : reduce the alkalinity of (as by neutralization)

de-alkylate \(ˈ)dē+\ *vt* [*de-* + *alkylate*] : to remove alkyl groups from (a compound) — **de-alkylation** \(ˌ)dē+\ *n* -s

deal lugger \ˈdē(ə)l-\ *n, usu cap D* [fr. *Deal,* municipal borough on the Strait of Dover, Kent, England] : a lugger formerly common on the southeast coast of England esp. in the ship-tender service

deal off *vi* : to deal the last hand of a poker game or the last hand in which one intends to participate

deal out *vt* : to omit (a specified player) from those to whom cards are dealt

deal pine *n* [[4]*deal*] : WHITE PINE 1a

deals *pl of* DEAL, *pres 3d sing of* DEAL

dealt *past of* DEAL

de-ambulatory \dē+\ *n* [LL *deambulatorium,* fr. L *deambulatus* + *-orium* -ory] : AMBULATORY

de-amidate \(ˈ)dē+\ *or* **des-amidate** \(ˈ)des+\ *vt* [*de-* or *des-* + *amidate*] : to remove the amido group from (a compound) — **de-amidation** \(ˌ)dē+\ *or* **des-amidation** \(ˌ)des+\ *n* -s

de-amidization \(ˌ)dē+\ *or* **des-amidization** \(ˌ)des+\ *n* -s : the process of deamidizing : DEAMIDATION

de-amidize \(ˈ)dē+\ *or* **des-amidize** \(ˈ)des+\ *vt* [*de-* or *des-* + *amide* + *-ize*] : DEAMIDATE

de-am-i-nase \(ˈ)dēˈamə,nās, -āz\ *also* **des-am-i-nase** \(ˈ)deˈsam-\ *n* -s [*de-* or *des-* + *amin-* + *-ase*] : an enzyme that hydrolyzes amino compounds (as amino acids) with the removal of the amino group

de-aminate \(ˈ)dē+\ *vt* [*de-* + *aminate*] : to remove the amino group from (a compound)

de-amination \(ˌ)dē+\ *or* **des-amination** \(ˌ)des+\ *n* : the process of deaminating ⟨the enzymatic oxidative ~ of glycine to glyoxylic acid and ammonia⟩ — compare AMINOLYSIS 2

de-aminization \(ˌ)dē+\ *n* -s : the process of deaminizing : DEAMINATION

de-aminize \(ˈ)dē+\ *vt* [*de-* + *aminize*] : DEAMINATE

[1]**dean** *var of* [1]DENE

[2]**dean** \ˈdēn\ *n* -s [ME *deen,* fr. MF *deien,* fr. LL *decanus,* lit., chief of ten, fr. L *decem* ten + *-anus* -an — more at TEN] **1** *obs* : a chief of 10 men : TITHINGMAN 1 **2 a** : a head over 10 monks in a monastery **b** : the head of the chapter or body of canons or prebendaries in a collegiate or cathedral church **c** : a priest of the Roman Catholic Church appointed by a bishop to supervise the affairs of a group of parishes within the diocese — called also *vicar forane* **3 a** : a resident fellow at an English university charged with the discipline rather than the instruction of undergraduates **b** : the head of one of the divisions, faculties, colleges, or schools of a university ⟨the ~s of several leading medical colleges⟩ ⟨the ~ of the faculty of arts⟩ ⟨the student must obtain the approval of the appropriate ~s and the chairmen of the departments concerned⟩ **c** : an administrative officer at a college or secondary school who counsels students on academic matters (as choice of program, maintenance of academic standing, honors, or failure) and who in addition has some disciplinary authority pertaining to such matters as breach of dormitory rules, unexcused absences, cheating and plagiarism, suspension, or dismissal ⟨~ of men⟩ ⟨~ of women⟩ ⟨~ of freshmen⟩ ⟨~ of the senior class⟩ **4** : a high officer of the orders of the Thistle and of the Bath who is always a clergyman — compare CHAPLAIN **5** : the senior of a group of men : DOYEN 1a

[3]**dean** \"\ *vi* -ED/-ING/-S : to act as dean ⟨was asked to ~⟩

dea-ner *var of* DEENER

dean-ery \ˈdēn(ə)rē, -ri\ *n* -ES [ME *denerie,* fr. *deen, den* dean + *-erie* -ery] **1 a** : the office or position of a dean **b** : the residence of a dean **2** : the jurisdiction of a dean

deanery of christianity *usu cap C* : any of various British deaneries comprising certain city or town parishes (as Exeter or Lincoln)

dean-ess \-nəs\ *n* -ES : a nun who serves as dean in a convent

dean of a peculiar : a titular dean of the Church of England either without peculiar jurisdiction (as the dean of the Chapels Royal) or with jurisdiction but without a chapter

dean of christianity *usu cap C* : a holder of one of certain rural deaneries in England

dean of convocation : the president of a convocation in churches of the Anglican Communion

dean of guild 1 : the head of a guild (as in medieval and some existing European guilds) having the power to summon the members to meetings **2** : a magistrate of a Scottish burgh or town formerly having jurisdiction of mercantile causes within a burgh and still entrusted with the inspection of and control over the construction, alteration, or repair of buildings

dean of the arches *usu cap D&A* [fr. the Court of *Arches,* the court of appeal for the province of Canterbury] : a lay judge in an ecclesiastical court (as the chancery court of the province of York) : the official principal of the archbishop of Canterbury

deans *pl of* DEAN, *pres 3d sing of* DEAN

dean schedule \ˈdēn-\ *n, usu cap D&S* [after Albert F. *Dean* †1933 Am. actuary] : a system for measuring the relative fire hazard and determining fire insurance rates for a property by an analysis of location, structural features, occupancy, and exposure

dean's list *n* : a list of students receiving special recognition from the dean of a college because of superior scholarship

[1]**dear** \ˈdi(ə)r, -iə\ *adj* -ER/-EST [ME *dere* brave, bold, hard, severe, fr. OE *dēor;* prob. akin to OE *dēor* beast — more at DEER] : SEVERE, SORE ⟨our *dearest* need⟩ ⟨his *dearest* enemies⟩

[2]**dear** \"\ *adj* -ER/-EST [ME *dere,* fr. OE *dēore;* akin to OHG *tiuri* costly, ON *dýrr*] **1** *obs* : GLORIOUS, WORTHY, HONORABLE **2** : regarded very affectionately or fondly : highly valued or esteemed : BELOVED ⟨ran for ~ life⟩ ⟨his son was very ~ to him⟩ ⟨the cause of democracy . . . is so ~ to us —M.R. Cohen⟩ — often used formally or affectionately in address ⟨*Dear* Sir⟩ ⟨my ~ James⟩ ⟨Mother ~⟩ **3** : LOVING, AFFECTIONATE, FOND ⟨for the ~ love I bear him⟩ **4 a** *obs* : SCARCE **b** : high-priced or expensive either absolutely ⟨butter is cheap when it is plentiful and ~ when it is scarce —G.B.Shaw⟩ or relatively ⟨that wretched suit would be ~ at any price⟩ **5** *obs* : VALUABLE, IMPORTANT **6 a** : close to the heart : present in mind : engaging the attention ⟨my ~*est* wish is for your happiness⟩ **b** : HEARTFELT, EARNEST ⟨one whose ~*est* prayer has been granted —G.B.Shaw⟩ **syn** see COSTLY

[3]**dear** \"\ *adv* [ME *dere,* fr. OE *dēore,* fr. *dēore,* adj.] **1** : DEARLY ⟨the effort cost him ~⟩ **2** : FONDLY, AFFECTIONATELY

[4]**dear** \"\ *n* -s [ME *dere,* fr. *dere,* adj.] **1** : a dear one : DARLING, SWEETHEART ⟨that kiss I carried from thee ~ —Shak.⟩ **2** : a lovable person ⟨pretty little ~s⟩ : an endearing person or being ⟨carry this in for me, like a ~⟩

[5]**dear** \"\ *vt* -ED/-ING/-S [ME *deren,* fr. *dere,* adj.] **1** *obs* : to make dear : make high-priced **2 a** : to address as *dear* **b** *obs* : ENDEAR

[6]**dear** \"\ *interj* [[4]*dear*] — used typically to express annoyance or dismay

dear-born \ˈdi(ə)r,bȯrn, -bərn\ *n* -s *sometimes cap* [after Henry A. S. *Dearborn* †1851 Am. politician and writer who maintained such a carriage] : a light 4-wheeled carriage with curtained sides

dearling *obs var of* DARLING

dear-ly *adv* [ME *derely,* fr. OE *dēorlīce,* fr. *dēore* dear + *-līce* -ly — more at DEAR] : in a dear manner: as **a** *obs* : PRECIOUSLY, WORTHILY, RICHLY **b** : with affection : FONDLY, AFFECTIONATELY ⟨to love one ~⟩ **c** : HEARTILY, EARNESTLY, DEEPLY, KEENLY ⟨the peace we so ~ seek —D.D.Eisenhower⟩ **d** : at a high rate or price ⟨the victory was ~ won⟩

dear-ness *n* -ES [ME *derenesse,* fr. *dere* dear + *-nesse* -ness] : the quality or state of being dear: as **a** : LOVABLENESS : endearing quality **b** : reciprocal affection : FONDNESS **c** : COSTLINESS

dearness allowance *n, India* : a bonus or pay increase to meet a rise in the cost of living

[1]**dearth** \ˈdərth, ˈdəth, ˈdəith\ *n* -s [ME *derthe,* fr. *dere* costly, dear + *-the* -th — more at DEAR] **1** *obs* : DEARNESS : highness of price **2** : scarcity that makes dear : WANT; *specif* : FAMINE ⟨there came a ~ over all the land of Egypt —Acts 7:11 (AV)⟩ **3** : lack of a present necessity : deficiency or inadequate supply of something (as news) or of some quality (as courage)

[2]**dearth** *vt* -ED/-ING/-S [ME *derthen,* fr. *derthe,* n.] *obs* : to make scarce, dear, or high-priced

deary *or* **dear-ie** \ˈdirē, -ri\ *n, pl* **dear-ies** [[4]*dear* + *-y, -ie*] : little dear : DARLING — often used as a term of address

deas \ˈdēs, -ā-,-e-\ *n* -ES [ME *deis, dees* raised table, raised platform — more at DAIS] *Scot* : BENCH, SETTLE; *esp* : one that can also be used as a table

de-ash \(ˈ)dē+\ *vt* [*de-* + *ash* (residue of combustion)] : to remove ash from

[1]**dea-sil** *also* **dei-seal** *or* **des-sil** \ˈdēzəl, ˈdes(h)əl\ *adv* [Sc-

[2]**deasil** \"\ *n* -s : a charm performed by going three times about an object in the direction of the sun and sometimes carrying fire in the right hand

de-aspirate \(ˈ)dē+\ *vt* [*de-* + *aspirate*] : to pronounce without aspiration

de-assimilation \ˌdē+\ *n* [*de-* + *assimilation*] : CATABOLISM

death \ˈdeth\ *n, pl* **deaths** \-ths *sometimes* -t͟hz\ [ME *deeth, deth,* fr. OE *dēath;* akin to OHG *tōd* death, ON *dauthi,* Goth *dauthus;* derivative fr. the root of ON *deyja* to die — more at DIE] **1** : the ending of all vital functions without possibility of recovery either in animals or plants or any parts of them : the end of life : the act, process, or fact of dying **2 a** : the cause or occasion of loss of life ⟨drinking was the ~ of him⟩ : a deadly weapon or agency ⟨a cobra with ~ in its fangs⟩ **b** *archaic* : PLAGUE — see BLACK DEATH **3** *usu cap* : the bringer of death personified and conventionally represented as a skeleton with a scythe : the destroyer of life : GRIM REAPER **4 a** : the state of being no longer alive ⟨in ~ as in life⟩ **b** : a joyless dull tasteless existence : the state of being without full possession or enjoyment of the intellectual or physical faculties ⟨the ~ in life of long years spent in a hospital bed⟩ **c** : cessation or absence of spiritual life variously conceived as alienation from God, deadness to the appeals of spiritual ideals, annihilation of the spirit as a result of sin, or irredeemable damnation — called also *spiritual death* ⟨to be carnally minded is ~ —Rom 8:6 (AV)⟩ **5** : the passing or destruction of something inanimate ⟨the ~ of the rackety old Third Avenue El —*Newsweek*⟩ or intangible ⟨the ~ of all his hopes⟩ ⟨the ~ of vaudeville⟩ : the process of such passing ⟨the ~ of the empire⟩ : EXTINCTION ⟨the ~ of a species⟩ **6** : CIVIL DEATH **7** : lethal or murderous violence : HOMICIDE ⟨merchants of ~⟩ ⟨a man of ~ —Francis Bacon⟩ **8** *Christian Science* : the lie of life in matter : that which is unreal and untrue : ILLUSION — **at death's door** : close to death : critically ill : in real or apparent danger of dying — **be death on 1** : to have marked talent for accomplishing or dealing with ⟨his approach shots are erratic but he *is death on* putts⟩ **2** : to dislike or oppose vigorously ⟨the boss *is death on* latecomers⟩ — **in at the death** : present at the conclusion of an event — **to death** *adv* : to the last extremity ⟨tired *to death*⟩ : beyond endurance : EXCESSIVELY ⟨that kind of plot has been done *to death*⟩ — **to the death 1** : to death **2** : as long as life lasts : to the end : without wavering or compromise ⟨war *to the death*⟩ ⟨follow our leader *to the death*⟩ ⟨hunting a criminal *to the death*⟩

death adder *n* : a highly venomous elapid snake (*Acanthophis antarcticus*) of the Australian region having a stout body and a spine on the end of the tail; *also* : any of several other related venomous snakes of Australia and Tasmania

death alder *n* [so called fr. its poisonous effect on cattle] : a spindle tree (*Euonymus europaeus*)

[1]**death angel** *n* : AZRAEL

[2]**death angel** *n* : DEATH CUP 1

death apple *n* : MANCHINEEL

deathbed \ˈ-ˌ-\ *n* [ME *deeth bed,* fr. *deeth* death + *bed*] : the bed in which a person dies : the last hours of life ⟨~ baptism⟩

deathbed deed *n, early Scots law* : a deed made after contracting a sickness that ended in death within 60 days after the date of granting and without such convalescence as is indicated by the grantor going unsupported to kirk or market

death bell *n* : PASSING BELL

death benefit *n* : money payable to the beneficiary or estate of a deceased under a policy of life or accident insurance or a pension plan

death bill *n* : an ecclesiastical list of dead to be prayed for

deathblow \ˈ-ˌ-\ *n* : a mortal blow ⟨he received his ~ in his first battle⟩ : a stroke or event that kills, destroys, or puts an end to

death board *n* : a plank on which a corpse is laid for sea burial

death camas *n* : any of several plants of the genus *Zigadenus* (as *Z. venenosus* and *Z. glaucus*) that cause poisoning of grazing animals in the western U.S.

death candle *n* : CORPSE CANDLE

death cell *n* : a prison cell for one awaiting execution

death certificate *n* : a certificate in which various information (as age, race, occupation) relating to a dead person is given and in which a physician certifies the cause of death

death chamber *n* : a room in which a person is dying or lies dead; *specif* : a place of execution within a prison

death-come-quickly \ˌ-(ˌ)-ˈ--\ *n, dial Eng* : HERB ROBERT

death cord *n* : a rope used for hanging a person — called also *death rope*

death cup *n* **1** *also* **death angel** : a very poisonous mushroom (*Amanita phalloides*) of wide distribution ranging in color from pure white (as usu. in the U.S.) to olive or yellow and having a prominent volva at the base **2** : the prominent cuplike enlargement at the base of the stipe in some fungi of the genus *Amanita* that is characteristic of poisonous forms though present also in some that are harmless

deathday \ˈ-ˌ-\ *n* [ME *deethday,* fr. OE *dēathdæg,* fr. *dēath* death + *dæg* day — more at DAY] : the day of a person's death or its anniversary

death duty *n, chiefly Brit* : DEATH TAX

death fire *or* **death light** *n* : DEADLIGHT 3, CORPSE CANDLE

death-ful \ˈdethfəl\ *adj* [ME *deethful,* fr. *deeth* death + *-ful*] **1** *archaic* : full of or threatening death : DEADLY, MURDEROUS, DESTRUCTIVE, BLOODY **2** *archaic* : liable to undergo death : MORTAL **3** : like death : having the appearance of death : DEATHLY ⟨on his ~ face . . . a look of pain and baffled anger —Richard Hofstadter⟩ — **death-ful-ly** \-əlē\ *adv*

death herb *n* : BELLADONNA 1

death house *n* : the section of a prison for persons awaiting execution

death-in \ˈdethən\ *n* -s [prob. fr. *death* + *in*] **1** : a water hemlock (*Cicuta virosa*) of Europe **2** : a poisonous plant (*Oenanthe phellandrium*) closely related to the water hemlock

death instinct *n* : unconscious or biological tendencies toward self-destruction

death knell *n* **1** : PASSING BELL **2** : an action or event presaging death or destruction ⟨the coming of the power press was the *death knell* of the hand press⟩

death-less \ˈdethləs\ *adj* : not subject to death, destruction, or extinction : IMMORTAL, UNDYING, IMPERISHABLE ⟨~ fame⟩ ⟨~ poems⟩ — **death-less-ly** *adv* — **death-less-ness** *n* -ES

death-like \ˈ-ˌ-\ *adj* : DEATHLY

death-li-ness \ˈdethlēnəs, -lin-\ *n* -ES : the quality or state of being deathly

death-ling \-liŋ\ *n* -s : one liable to death : MORTAL

[1]**death-ly** \ˈdethlē, -li\ *adj* [ME *dethlich* deadly, mortal, fr. OE *dēathlic* mortal, fr. *dēath* death + *-līc* -ly] **1** : DEADLY, FATAL, MORTAL, DESTRUCTIVE **2** : like or having the characteristics of death ⟨a ~ stillness⟩ **3** : of, relating to, or suggestive of death ⟨I marked each ~ change in him —Robert Browning⟩ **syn** see DEADLY

[2]**deathly** \"\ *adv* : in a way or to a degree resembling or approximating death ⟨~ sick⟩

death march *n* : a march (as of prisoners of war) in which those unable to go on are left to die as they fall

death mask *n* : a cast taken from the face of a dead person

death penny *n* **1** : a coin placed with a buried corpse as if to pay passage to the otherworld **2** : DEATH WEIGHT

death point *n* : a limit (as of degree of heat or cold) beyond which an organism or living protoplasm cannot survive

death rate *n* : the ratio between number of deaths and number of individuals in a specified population and period of time usu. expressed as number of deaths per hundred or per thousand population

death rattle *n* : a rattling or gurgling sound produced by air passing through mucus in the lungs and air passages of one dying

death rope *n* : DEATH CORD

death row *n* : a row of death cells

deaths *pl of* DEATH

death's-head \ˈdeths,hed\ *n* **1** : a human skull as the emblem of death : the head of Death **2** : a finger ring bearing the figure of a skull