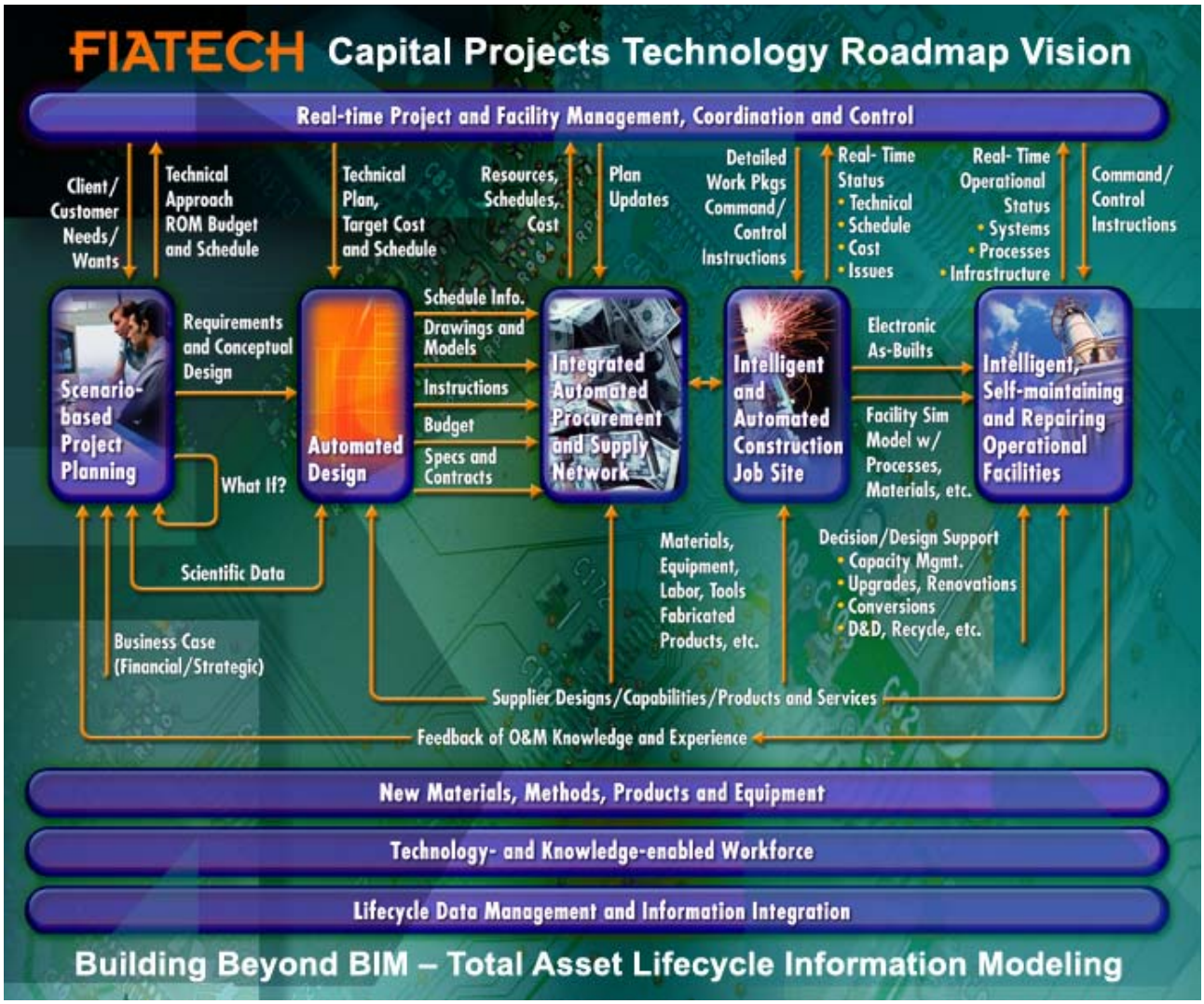
# Appendix C: FIATECH Capital Projects Technology Roadmap

## Overview

The Capital Projects Technology Roadmap (CPTR or the Roadmap) is a cooperative effort of associations, consortia, government agencies, and industry, working together to accelerate the deployment of emerging and new technologies that will revolutionize the capabilities of the capital projects industry. The initiative is led by FIATECH and is open to all stakeholders who are committed to the future success of the capital projects industry.

The Capital Projects Technology Roadmap presents a vision for the capital projects industry and a strategy and plan for achieving that vision. Representatives from all areas of the industry have come together to create this work. This is their vision, and their foundation for investment in the future.

***"Fully integrated and highly automated project processes coupled with radically advanced technologies across all phases and functions of the project/facility lifecycle"***




This vision is captured in the guiding model for the Capital Projects Technology Roadmap in the figure above. This model depicts a completely integrated structure composed of nine critical elements and can be thought of as a virtual enterprise for the future.

For more information on the FIATECH Capital Projects Technology Roadmap, its individual elements and their respective projects, visit: http://www.fiatech.org/projects/roadmap/cptri.htm.

## Element 1: Scenario-based Project Planning

### Vision

The future project planning system will provide interactive evaluation of project alternatives, enabling creation of conceptual designs and project plans that best meet the needs of all stakeholders. This collaborative planning environment will provide full awareness of the impacts of decisions on costs, schedules, and lifecycle performance. The system will provide the initial input to a comprehensive project plan and specifications, ultimately captured in an Asset Lifecycle Information System, to guide subsequent project designs and support downstream project functions.

### Scope

Provides a comprehensive, collaborative project planning system that captures and analyzes front end data (including business case, scientific data, what-if scenarios, requirements and conceptual design, customer needs, budget and scheduling, and feedback from operations and maintenance) to assist the planning team as well as to provide the initial data capture to be used throughout the lifecycle of the facility.

### Technology

Business Intelligence, Scenario modelling, Knowledge Management, Collaboration, Workflow, Data Mining, Simulation, Process recording, Document Management, Visualization

### Stakeholders and Foreseen Benefits

| Stakeholder | Specific Benefits |
|---|---|
| Owners/Operators | Rapid and complete agreement on what will be designed, built, and operated - reduces cost, risk, and project cycle time. Considers views of all stakeholders. |
| Research and Development (R&D) Teams | Seeks alignment on project technology and provides a clear direction on further development required. |
| Designers/Engineers | Accurate and complete electronic definition of project requirements - reduces design time, eliminates ambiguities, and reduces technical risk. |
| Constructors | Provides a voice in the early phases to ensure constructability, reduce risks, and eliminate unnecessary challenges - reduces build time and cost |
| Material/Equipment/Technology Suppliers | Enables early start on long lead items, more cost-competitive solutions through clear specification of requirements, and early mitigation of technical and schedule risks |

### Focus Areas

- E1-FA1: Work Process Mapping
- E1-FA2: Industry Tool Survey
- E1-FA3: Reference Data Requirements
- E1-FA4: Functional Requirements
- E1-FA5: Data Model Requirements
- E1-FA6: Design & Develop Next Generation Tools and Database

## Element 2: Automated Design

### Vision

Current and emerging capabilities in 3-D design, analytical modelling and simulation, intelligent systems and distributed information management offer the opportunity to create a truly integrated and automated project design environment. In this environment, all tools will work together as an interconnected system that provides all of the functionality needed to develop and validate detailed designs for every aspect of a project based on the design criteria. This integrated design environment will dramatically reduce the time and cost in moving from concept to construction execution through automation of complex design engineering tasks. It will also greatly reduce errors and liability through comprehensive, automated design optimization and verification. Optimization would include a variety of options including total installed cost, total lifecycle cost, and plant output.

### Scope

Provides the forum for an industry-wide set of design automation features and specifications to be created that will be available for software vendors to use when developing improved design automation software. Also provides a design automation information clearing house that will serve as a knowledge management resource. Enables industry stakeholders and software vendors to work collaboratively to develop improved design automation technology for the capital projects industry.

### Technology

Knowledge Management, Collaboration, Standards, Simulation, Rules Based Design, Change Management, Risk Assessment

### Stakeholders and Foreseen Benefits

| Stakeholder | Specific Benefit |
|---|---|
| Owner/ Operators | Full assurance that designs are in direct response to requirements and optimized to meet the needs and constraints of all stakeholders –reducing total cost of ownership over the life-cycle, shortening timelines to completion, mitigating risks, and providing clear visibility of risks. |
| Architects | Improved efficiency in translating concepts to buildable designs; enhanced ability to translate design capabilities into innovative design solutions Improved ability to integrate the entire design team, including the owner, to reduce changes in scope or design later in the design process and during construction. |
| Designers/ Engineers | Improved capability and efficiency through built-in analytical and validation tools, automation of all routine tasks, and mathematically accurate visualization of all aspects of the project design with respect to Owner project requirements, building codes, and applicable standards. |
| Constructors | Delivered contract documents will provide a complete and totally optimized and synchronized build plan. The Building Information Model and related electronic documentation will support fast, flawless execution with zero wasted time, effort, and resources. |
| Material/ Equipment/ Technology Suppliers | Clear, complete and unambiguous definition of all materials, parts, products, equipment, and other procured resources will enable more cost-effective operations; connectivity to design team will provide streamlining the processes for bidding and construction submittals. |
| Design software vendors | Vendors need to understand the market benefits associated with developing products that embrace the vision of an automated design environment before they will make decisions to invest in its development. A chorus of clear, concise and unified voices providing a common message will create incentives to the software vendors to enhance their products quickly and support the automated design vision. Regardless of the proprietary software applications, it is imperative that all data can be exchanged between these platforms using open standards for interoperability, so there is no rework or multiple input of data information. |

### Focus Areas

- E2-FA1: Metrics for proof of concept and demonstration of capabilities
- E2-FA2: Design Viewing
- E2-FA3: Integrated/Interoperable Design Systems
- E2-FA4: Intelligent Design Systems
- E2-FA5: Create and maintain a design automation information clearinghouse

## Element 3: Integrated, Automated Procurement & Supply Network

### Vision

The procurement system of the future will be seamlessly integrated with the project design system, project management and control system, finance system, field materials management system and the global supply network. This will enable enterprises and project teams to optimize work packages, select products, identify qualified suppliers, and procure the best products at the best prices with complete confidence and ability to deliver on time and within budget. These linked systems will automatically track every order through delivery to the job site, orchestrate the flow of resources for optimal build efficiency and provide instant visibility of progress and variances against technical, schedule, and cost requirements throughout the selection, delivery and payment processes.

### Scope

Provide a fully integrated, automated procurement and supply management system (i.e. tools and processes for planning, controlling, including financial controls for the procurement process.)

### Technology

Supply Chain, Procurement, Project scheduling and control, Logistics, Materials Handling, Dynamic Mapping and Simulation of Supply Chain, Standards, AEX, Work Process.

### Stakeholders and Foreseen Benefits

| Stakeholder | Specific Benefit |
|---|---|
| Owner/ Operators | - Reduced efforts in capital project business development and estimating phases<br>- Reduced costs and assured best value in all procurement actions<br>- Faster development/preparation of inquiries<br>- Reduced bid cycle time |
| Architects | - Easy access to product feature and cost information to enhance innovation and affordability of design concepts. |
| Designers/ Engineers | - Reduced efforts in capital project business development and estimating phases<br>- Full access to design data for purchased materials, components, and equipment will enable better designs and eliminate disconnects between design specifications and delivered products<br>- Faster development/preparation of inquiries<br>- Reduced bid cycle time<br>- Higher quality specifications (with early owner input), RFQ, BID, POs will help to reduce downstream changes and associated cost<br>- Reduced time for inspection activities |
| Constructors | - Reduced efforts in capital project business development and estimating phases<br>- Reduced bid cycle time<br>- Higher quality specifications, RFQ, BID, POs will help to reduce downstream changes and associated cost<br>- Reduced time for inspection and on-site receiving activities<br>- On-time delivery of exactly the right resources to point of need, tightly synchronized to the project schedule, will speed construction, eliminate downtime, and drastically simplify site staging requirements. |
| Material/ Equipment/ Technology Suppliers | - Clear and definitive agreement on cost, delivery, product specifications, and conditions of contracting<br>- Higher quality RFQ, BID, POs will help to reduce downstream changes and associated cost<br>- More efficient sales/business development processes<br>- Reduced bid cycle time<br>- Reduced time for inspection activities |

### Focus Areas

- E3-FA1: Integration of Engineering and Project Controls with Procurement
- E3-FA2: Supply Chain Information Access and Standards
- E3-FA3: Integration of Procurement with Intelligent Job Site
- E3-FA4: Evaluation of Supply Chain Structures

## Element 4: Intelligent & Automated Construction Job Site

### Vision

Provides the forum for construction practitioners, material providers and technology providers to make a concerted and systematic effort to identify, develop, deploy and evaluate the impact of the components, systems, standards and deployment strategies that are needed for successful Intelligent and Automated Construction Job Sites.

### Scope

Construction sites will become more "intelligent and integrated" as materials, components, tools, equipment, and people become elements of a fully **sensed and monitored environment**. Location and status of all materials, equipment, personnel, and other resources will be continuously tracked on site, thus enabling a "pull" environment where needed resources are delivered on demand. **Automation of construction processes** will augment manual labour for hazardous and labour-intensive tasks such as welding and high-steel work. Construction job sites will be **wirelessly networked** with **sensors** and communications technologies that enable technology and knowledge-enabled construction workers to perform their jobs quickly and correctly.

### Technology

Smart Chips (RFID and Sensors), Wireless Technology, Location Based Systems, Mobile Devices, Displays, Work Package Optimization, Construction Automation, Pre-fab/Materials, Survey and Positioning, Modeling and Simulation, Skills Certification, Asset/Site Security

### Stakeholders and Foreseen Benefits

Main benefits are to the construction site. Key features and associated business benefits at a site level as are follows:

| Feature | Direct Business Benefit |
|---|---|
| Model-driven, highly sensed job site environment | -Dramatically improves communication between constructors, engineers and suppliers<br>-Delivery of material as needed and reduced costs for storage and lost material<br>-Real-time problem identification and fast resolution<br>-Streamlined workflows reduces build time and cost<br>-Reduce of lost/stolen materials, products, tools, and equipment<br>-Elimination of redundant data entry and entry errors |
| Continuous visibility of performance vs. plan | -Fast identification and accurate scoping of changes and variances<br>-Accurate capture of costs to improve planning and competitiveness for future projects |
| Automated, highly accurate capture of as-built data fed to Asset Lifecycle Information System | -Reduces schedule slips due to continuously current visualization aids used for engineering constructability issues in-process<br>-Eliminates cost of "unpleasant surprises" during operational startup<br>-Shortens handover and start-up timelines |
| Highly visible sequencing and schedules from multiple parallel activities | -Enables increased concurrency of activities to reduce build time |
| Automatic generation of work orders, resource allocations, and schedule with highly integrated material flow | -Reduces downtime<br>-Reduces time and space requirements for staging and storing material on site<br>-Reduces working capital requirements for held inventory |
| Technology-enabled workers | -Greatly increases productivity |

### Focus Areas

- E4-FA1: Standards and Practices
- E4-FA2: Field Information Systems
- E4-FA3: Positioning and Tracking
- E4-FA4: Construction Equipment and Technology

## Element 5: Intelligent Self-maintaining and Repairing Operational Facility

### Vision

Future capital facilities will be programmed, designed and constructed to be an intelligent integrated system of systems. These intelligent systems will utilize the data flow from self monitored equipment and systems to manage the actions necessary to ensure conditions and performance necessary to enable safe, secure, and continuously optimized facility operations. Facility systems will be totally integrated to utilize data generated during operation to automatically and autonomously activate built-in mechanisms to perform required maintenance and/or repair functions. If necessary, instructions will be automatically communicated to external support systems when the required actions are beyond the capabilities of the built-in mechanisms. A comprehensive network of sensors and decision support systems will provide continuous visibility of operational status and performance, providing trends for systems and flagging problems with recommendations for external intervention. Information from the embedded systems will provide feedback to future programming/design/ construction operations in support of the business and/or regulatory environment to ensure optimal facility utilization, even during response to crises.

### Scope

Intelligent Self Maintaining and Repairing Operational Facilities provides the mechanisms for utilization of data to manage the actions necessary to ensure conditions and performance necessary to enable safe, secure and continuously optimized maintenance and operations.

### Technology

Sensors, GREEN, LEED, BIM, Sustainability, Automated/Integrated Decommissioning and Demolition, Real Time data, Modeling and 4D Simulation, Facility Monitoring/O&M

### Stakeholders and Foreseen Benefits

| Stakeholder | Specific Benefit |
|---|---|
| Owner/ Operators (including O&M)/ Commercial Real Estate | - Continuous optimization of performance and profitability across the entire facility life<br>- Reduced risk, liability, and total cost of ownership<br>-"Disaster-proof" operations<br>-Improved ability to respond to changes in the business environment -Facility condition assessment will lead to better and more effective use of funds and personnel |
| Occupants/ Tenants/ Service Providers | -Access to information for optimizing operations and tasks |
| Architects | -Feedback of O&M experience and lessons learned to continuously improve design of future facilities |
| Design/ Engineers | -Feedback of O&M experience and lessons learned to continuously improve future facility designs<br>-Enable effective facility upgrades, renovations, and conversions to alternate use |
| Construction | -Radically reduced time and cost of operational start-up and handover<br>-Accelerated ramp-up to full operating capability |
| Material/ Equipment/ Technology Suppliers | -Greatly expanded opportunity for product evolution to support next-generation facilities in all sectors of industry |
| Insurers/ Finance/ Energy Providers | -Reduction and control of risk (perception) |

### Focus Areas

- E5-FA1: Facility Condition Assessment
- E5-FA2: Facility Performance
- E5-FA3: Information Exchange
- E5-FA4: Intelligent Materials
- E5-FA5: Catastrophic Event Mitigation and Recovery Technologies
- E5-FA6: Automated/Integrated Decommissioning and Demolition Techniques & Technologies

## Element 6: Real-time Project and Facility Management, Coordination and Control

### Vision

Future management systems will empower integrated orchestration and control of Project and Facility processes, and will be a tool that provides continuous visibility to all plans and tasks throughout the planning, design, construction and facility lifecycle. The result will be a well-orchestrated series of interrelated tasks and activities optimized for efficiency and results, coordinating resources and plans in an error-free fashion, radically reducing the time and cost required to move from planning to design to construction to operation.

### Scope

Provides a fully integrated facility planning and management system (i.e. tools and processes for planning, control, and review, including financial controls - of design, construction, and ongoing facility management). While Project and Facility Management are classically treated as separate and distinct sets of processes with a discrete handoff point, this Element treats them as a single set of processes covering the continuum from initial planning to the end of life of the facility.

### Technology

Project Management, Data Information Repositories, Real Time Information, Process Models, Performance Management and Assessment, Change Management, Quality Metrics, Financial Standards, Decision Support Tools, Standards for Project Data, Workflow, Cost Models.

### Stakeholders and Foreseen Benefits

| Stakeholder | Specific Benefits |
|---|---|
| Owner/ Operators<br>Facility Managers | - Full and continuous awareness of project status enables fast, sure response to issues, leading to more effective facility turnover and operation.<br>- Better knowledge management will lead to project efficiencies, multiple plant efficiencies, and reduced design, construction, and operating costs resulting from shared maintenance and operations procedures, parts, and reduced costs from prototypical upgrades. |
| Design Firms | - Feedback of comprehensive information will enhance conceptual design capabilities, reusable designs, and the process of issuing the design to users.<br>- Extensive feedback loop (constructability, etc), will lead to reduced errors and omissions and field rework/redesign |
| EPC Firms | - Highly responsive and efficient change management<br>- Early and accurate feedback on design performance and compliance. |
| Project/ Construction/<br>Program Managers | - Clear and current visibility of status and progress of all tasks, early warning of problems, and quick access to information and resources for problem-solving. |
| Material/ Equipment/<br>Technology Suppliers | - Instant access to information concerning their obligations to the project and an ability to mesh materials and technologies in a just-in-time environment.<br>- More rapid pay cycles |

### Focus Areas

- E6-FA1: Intelligent Project Management System
- E6-FA2: Streamlined, knowledge-driven approval processes
- E6-FA3: Optimized Construction Sequence and Schedule
- E6-FA4: Real-Time, Model Based Project and Facilities Control
- E6-FA5: Automated, Distributed Change Management
- E6-FA6: Automated Quality Assurance and Quality Control
- E6-FA7: Integrated Stakeholder Business Systems
- E6-FA8: Verification of Financial performance

## Element 7: New Materials, Methods, Products & Equipment

### Vision

New materials, methods, and equipment will enable rapid, low-cost construction of modularized, lightweight structures in a fraction of current time spans by applying highly engineered fabrication and assembly methods. Flexible and "programmable" properties will enable new generations of stronger, lighter materials to be easily transported, placed, formed, cured, and attached with little or no temporary support. New and improved processes engineered for efficiency will radically reduce labour and material costs. Self-assembling robotically controlled, and automatically activating components will replace the most troublesome of today's processes.

### Scope

Provide an industry-focused Clearing House for New Materials, Methods, Products and Equipment. Also, identify and manage the content to go into one or more of the shared or common knowledge bases. For example, identify common industry-adopted methods or practices as well as materials and equipment information.

### Technology

Knowledge Base, Smart Materials and Components/Assemblies, Reconfigurable Materials, Automation Integrated into Materials, Model-driven Construction Systems, Engineering for Automated Construction, New Connection Technologies and Methodologies, Standardized Construction Components, Low-impact Site Prep, Improved Joining, Zero Temporary Structures, Intelligent/Interactive Construction Equipment and Systems, Programmable Nanomaterials and Nanoconstructors, Biomimetic Materials/ Structures and Facility Systems, Non-intrusive Autonomous Effectors, Legacy Integration and Emulation Technologies, Advanced Materials for Reinforcement and Resurfacing, Lean Construction, Autonomous Robots.

### Stakeholders and Foreseen Benefits

| Stakeholder | Specific Benefit |
|---|---|
| Owner/Operators | Better facilities at lower cost. |
| Architects | Specification and utilization of new materials and processes enables innovation in facility design. |
| Designers/Engineers | An expanded array of better options. |
| Constructors | More efficient processes. Elimination of the time and cost of temporary fixtures, wait times, etc. |
| Material/ Equipment/ Technology Suppliers | New opportunities to develop products and services - especially for global markets. |

### Focus Areas

- E7-FA1: Establish and maintain the new materials and methods coordination role
- E7-FA2: Establish and maintain a knowledge base of new materials and methods

## Element 8: Technology- & Knowledge-enabled Workforce

### Vision

Skilled and committed workers, enabled by technology and empowered by "knowledge at their fingertips" will perform to new levels of productivity. Workers in all functions of the capital projects enterprise will be enabled by technology that assists them in doing their jobs more effectively. Traditional divisions of labour and skills will be redefined, from the top floor to the trenches, to broaden the capabilities and value of every worker in the emerging team-based project environment. Redefined organizational allegiances and incentives will result in a more stable and reliable labour supply for all of the industry. A "knowledge supply chain" will assure the ready and consistent supply of the right workers with the right skills.

### Scope

Provides a focus on the human implications of technology for the capital projects industry. Properly trained and skilled labour supply. Improved skills and knowledge empowerment. Improved productivity and employment security, safety, health, and environmental compliance

### Technology

Knowledge base, Collaboration, Knowledge Supply Network, Incentives and Rewards, On-demand training, Interactive Work Instructions, Rugged Information Systems, Worker Certification and Verification Systems.

### Stakeholders and Foreseen Benefits

| Stakeholder | Specific Benefit |
|---|---|
| Owner/Operators | Ready supply of skilled and trained workers invested in enterprise success; greatly improved flexibility to respond to changing business requirements. |
| Architects | Confidence in ability of workforce to execute designs, particularly in complex project environments. |
| Designers/Engineers | Reduced learning curves for leading-edge tools; higher confidence in ability of workforce to translate designs to reality. |
| Constructors | Greatly improved skills and labour flexibility; assured compliance with HSE and technical requirements; improved workforce stability. |
| Material/Equipment/ Technology Suppliers | Significant reduction in problems at end user level. |

### Focus Areas

- E8-FA1: Skilled and Committed Workforce
- E8-FA2: Knowledge Management for Capital Projects Industry
- E8-FA3: Collaborative Business Process Management and Workflow

## Element 9: Lifecycle Data Management & Information Integration

### Vision

The long term vision of Element 9 of the Capital Projects Technology Roadmap (the Roadmap) is that the execution of future capital projects and operation of capital facilities will be radically enhanced by seamless access to all data, information, and knowledge needed to make optimal decisions in every phase and function of the capital project/facility lifecycle. Element 9 (Lifecycle Data Management and Information Integration) provides a foundation layer for the highly automated project and facility management environment envisioned in the Roadmap.

### Scope

Provides the standards, models, classifications and other mechanisms for both data management and information exchange for the industry. Includes the foundation for and programs to create and maintain shared or common knowledge-bases. Enables and motivates individual organizations to accelerate the process to create and deploy an Asset Lifecycle Information System: i.e. a fully integrated solution in which the standards, models, classifications and other mechanisms are implemented for a specific project or facility.

### Technology

Data transfer standards, interoperability, knowledge bases, asset life cycle information system, model-based information management, ontologies, digital models, expert rule-based systems, object repositories, process simulation, lifecycle data management system, reference data libraries, ISO 10303, ISO 15926, ISO 12006, IAI/IFC, FIATECH/cfiXML, W3C XML, FIATECH/AEX, etc.

### Stakeholders and Foreseen Benefits

| Stakeholder | Benefits |
|---|---|
| Owner/Operators | True integration of business and technical systems across all functions, all phases of the lifecycle, and all members of the supply chain will reduce capital costs and operating expenses, enable real-time responsiveness, and eliminate sources of error and problems. |
| Architects | One time data entry; seamless integration with design/engineering functions. |
| Designers/Engineers | Instant access to accurate data for design, analysis, engineering, and requirements management; transparent integration of all applications. |
| Constructors | Right knowledge and data available on demand to accomplish every task quickly, surely, correctly - and solve problems before they impact performance. |
| Material/Equipment/ Technology Suppliers | Seamless integration into any supply chain, with direct linkage to customers; eliminate need to support multiple systems (design, purchasing, etc.) for multiple customers. |
| Information Technology Groups | Reduced focus on inventing ways to store and exchange data. Increased focus on supporting the business needs of their clients |

### Focus Areas

- E9-FA1: Requirements and Feasibility
- E9-FA2: Technical Framework
- E9-FA3: Shared or Common Data
- E9-FA4: Asset Lifecycle Information System Deployment