A SIMPLE FRAMEWORK FOR INTEGRATED PROJECT DELIVERY

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ABSTRACT

This paper outlines a "Simple Framework" for Integrated Project Delivery. The starting point of this paper is the value made possible by the physical product, a "high performance building" (HPB). It is composed of highly integrated systems that are buildable, useable, operable, and sustainable. "Process Integration" is the integration of value and design, builders and operators' knowledge and sustainable design principles, materials and technologies. Process Integration can only occur in an "Integrated Organization" in which team members can decide, coordinate, work and decide effectively. The integrated organization makes possible and leverages "Integrated Information," where information is created once and used by all. The IPD contractual agreement, the ways people measure value, model and simulate to predict outcomes, collaborate, and manage production enable the integration required to deliver a high-performance building.

KEYWORDS

Integrated Project Delivery, Integrated Concurrent Engineering, high-performance building, integration, collaboration, lean construction, value.

INTRODUCTION

We offer a new perspective on Integrated Project Delivery (IPD) in which the strategies for organization; work methods and processes, and information management are derived from the value created through design and construction of a building. We describe a "Simple Framework" for a delivery system based on the body of knowledge developed through years of research and teaching on the application of Virtual Design and Construction carried out by faculty, students, and industry collaborators of the Center for Integrated Facility Engineering at Stanford University and years of practice with IPD and VDC. Virtual Design and Construction (VDC) is the use of multi-disciplinary performance models of building projects, including their products (facilities), organizations, and work processes for business objectives.

The Simple Framework builds on the American Institute of Architects (AIA) guide to IPD (AIA, 2007) and on the organization-process-contract perspective on IPD of the lean community (Thomsen et al., 2009). It expands these two perspectives by deriving the areas of integration required from the desired performance of the built

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structure and adds the explicit product integration and information integration perspectives to the organization and process focus of the existing IPD frameworks. In our practice, this Simple Framework has been useful for guiding the formation and work of IPD teams and for organizing teaching curricula and research efforts. Starting from the potential value created in the physical product is not only consistent with lean theory, it also opens possibilities for producing better outcomes in the form of a high-performing building delivering economic, social, environmental, and user value through leveraging VDC.

A SIMPLE FRAMEWORK

Facility owners and users envision a new or renovated facility as a high-performing facility. A facility functions as a whole, with all of its technical systems and social organizations supporting each other or fighting each other depending on the synergies or lack thereof created by the facility's designers and builders. Consider the case of a building with a high-performing, but complex energy management system consisting of passive and active energy management strategies and a complex building automation system operated by a facility management organization accustomed to managing many simple buildings and thus not staffed or trained to consider the amount of data and decisions the complex energy management system requires. As a result, the complex building that should be high-performing fails to achieve its promise. (Scofield, 2002; Kunz et al., 2009).

The best strategy to achieving a high-performance building is to create synergies between the technical systems that make up the facility and between the facility users and operators (Fig. 1). These synergies are best generated through integrating these systems as much as possible, i.e., through product integration.

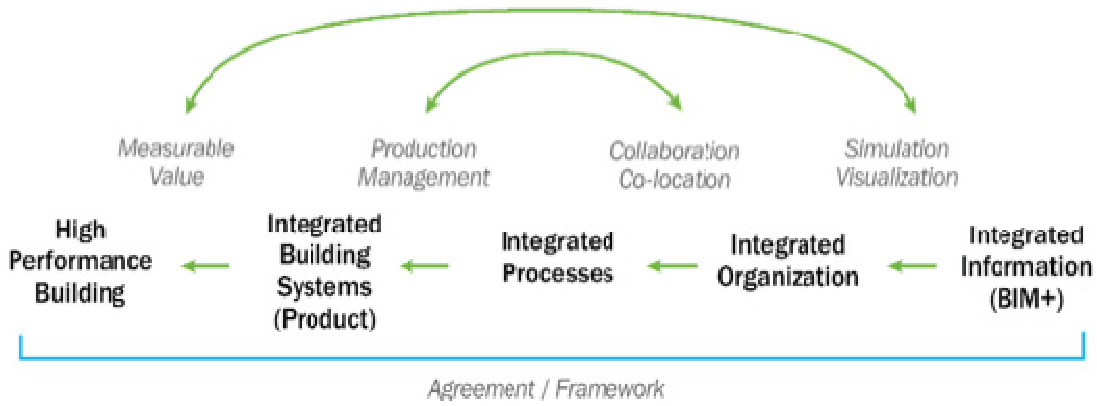

Figure 1: How integration of product, process, organization, and information supports the creation of a high-performance building (Fischer et al., 2012).

The Simple Framework is best understood by working backwards, from the product, which integrated project teams have agreed to deliver. A "high-performance building" must be useful to or usable by its occupants, it must be buildable safely within the time and money budgets available, it must be operable so that the building managers can create the right environment for the occupants with a commensurate expense, and finally, a building must be sustainable in its economic, environmental, and social context. A high-performance building is able to demonstrate that it meets the values and objectives stated by the owner at the beginning of the project, using specific metrics developed to evaluate its achievement.

A high-performance building is comprised of highly integrated systems, where systems are designed to work together and complement each other. To work together effectively, teams must have a way of communicating reliably and efficiently. "Integrated information," which supports simulation and visualization, and the easy access to that information, are used heavily to create a transparent and integrated process, in which all members of the team understand the work at all times. Simulations and visualization enable team members to share their knowledge effectively, to experiment, test and evaluate their ideas, to compare good solutions to poor solutions, and to communicate with other team members and stakeholders.

Meaningful metrics, not simply data collected for the sake of having numbers in a chart, must be used both to track how well a team is performing, and how closely the building conforms to the goals and values of the owner. Metrics are essential to understanding and, if need be, correcting team performance during the process.

Upholding the entire IPD system is a contractual agreement and framework (Ashcraft, 2012), which sets the "ground rules" for the project, and reinforces the idea that decisions can and must be made for the good of the project, not just for individual benefit. The contract will encourage and enable an integrated delivery system, and allow organizations and individuals to share information, collaborate, innovate, and challenge each other without fear of retribution.

THE HIGH-PERFORMANCE BUILDING

A high-performance building is one that can be constructed in a safe, effective way; it is easy and efficient to maintain; it is well-suited for whatever it is used for; and it does not harm people or the environment. A truly high-performance building supports its end users in performing their activities as optimally as possible; it is the "right" building for what the users need. For example, a school should allow teachers to educate, inspire, and engage with students, a hospital should enable doctors and nurses to heal sick people, and so on. This may seem like obvious performance criteria, however what sets a high-performance building apart is its level of success in terms of measurable value.

Delivering a high-performance building begins with an intense effort to understand and define the purpose of the building, how to measure that purpose, and how to best achieve it (Korkmaz et al., 2010). Crucially, stakeholders from every stage of the process must be involved in the design phase, since each stage shapes the building and its performance. A high-performance building also efficiently uses energy, materials, and labor during both the delivery and operating phases, which lowers first and lifecycle costs and other impacts. Traditional practice focuses primarily on design and construction cost only. But all buildings have a lifecycle cost (Whyte 2011) that must be paid and that in traditional practice is left mostly to chance.

INTEGRATED SYSTEMS

The key aspects of a high-performance building work in concert, not in conflict with each other. For this reason, no system or element of a high performing building can be designed in isolation. Electrical engineers cannot specify the appropriate amount of power without knowing what people and equipment will be working in the building; mechanical engineers must account for the size of the interior spaces and what will be done in them along with the composition and layout of the exterior skin, etc. Thus, every discipline must work collaboratively with all the others, informing each others' designs to create a building that truly functions as a whole, not just as an amalgamation of many disparate parts.

Every building consists of many systems (foundation, structural, envelope, energy management, etc.), each with their own primary function. Even a simple building has basic systems that must work symbiotically; a waterproof façade and roof alone require seamless coordination of many sub-system designers, fabricators, and builders. Yet, we often break up installation of the façade into separate contracts, which makes achieving a high-performing façade challenging because no one subcontractor is fully responsible for the performance of the entire system.

PROCESS INTEGRATION

Experience teaches building owners and delivery teams that all of the systems must be highly integrated to make high performance buildings possible. We can't just design all these different aspects of the building independently; we must design the systems together, all at once. Take lighting, for example. If you're going to design lighting, you have to think about the factors affecting daylight such as building width and floor-to-floor height. Will there be shear walls and / or cross-braces? What is the exterior aesthetic and how will that affect the amount of glazing? What is the interior layout: open or private offices, or a combination? Will there be labs? How wide will the corridors be? How large will the services core be? The integration of the processes – not just the processes themselves – is the key point here. We can't let people work in isolation and assume that the systems they design will somehow integrate into an optimal building.

The output of the design phase must be the design of a facility that is valuable for its users, can be built, can be operated, and is sustainable. It follows that there are five main process integration needs as shown in Fig. 2.

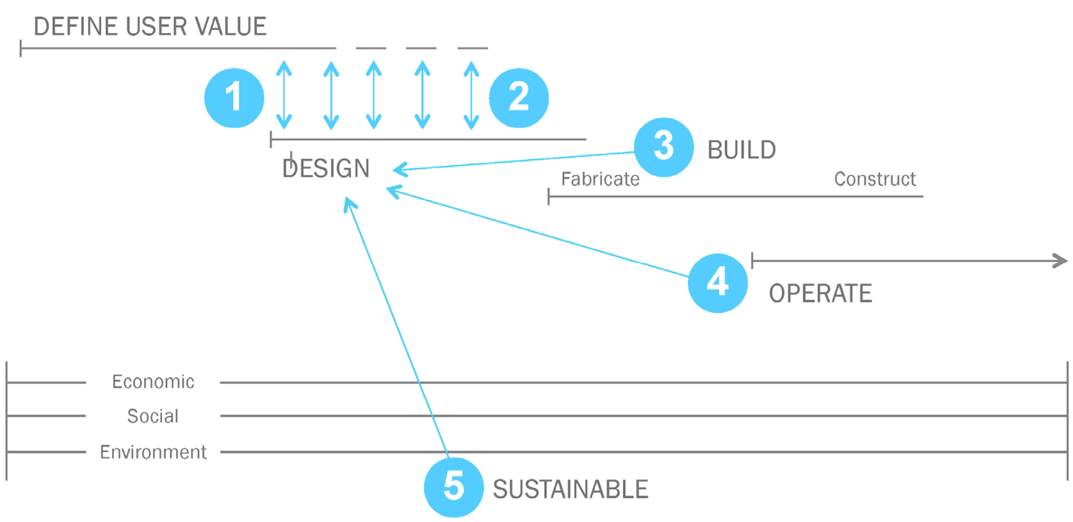

Figure 2: The five types of process integration to achieve high-performing facilities.

- 1. There must be some overlap (integration) of the value definition and design process because users won't be able to articulate what they want and what's valuable for them unless they see possible designs and their cost and value.
- 2. As the design gets detailed it must be validated against all user values over and over again and the value or the design adjusted when they get out of sync.
- 3. The construction perspective must be brought into the design process because the creation and documentation of a buildable design is a key design output. This cannot happen without the input of those who know how to build.
- 4. Bringing operational knowledge, i.e., how to run the facility during the use phase, to the design phase is also critical because creating a design that can be operated is, of course, also a key task for the integrated design team.
- 5. The integrated project team must consider knowledge about the sustainability of a building through its entire lifecycle within its economic, social, and environmental context. Even if a building was “perfect” for its users and easily buildable and operable it needs to have a positive triple bottom line to make it sustainable (Elkington, 1998).

These process integration needs focus on design because that's when a facility really takes shape in response to ideas, needs, and wishes of the facility owner and users. With a clear strategy for addressing the five integration needs, we increase the likelihood of achieving a design that's valuable for the users, can be built, can be operated, and is sustainable.

INTEGRATED ORGANIZATION

There are four tasks every project team must do well to succeed. **Leadership**, **coordination**, and **decisions** are required to perform **work** that adds value. Without these, team members and all the sub-teams will have difficulty integrating the processes that lead to a high-performing facility with integrated systems. Team members with the most experience and responsibility must set up the coordination scopes and mechanisms and help team members and owner stakeholders determine which decisions must be made, when and how to advance toward the project goals, etc.

To advance a project, team members must carry out the following work to enable the best decisions (Garcia et al., 2005). They must describe the alternatives currently under consideration from the perspective of their disciplines and explain the current alternatives to each other (Fig. 3). They must predict the expected performance of the design alternative so that the team can evaluate whether the design meets the owner’s goals and objectives and negotiate with each other how the alternatives should be adjusted to improve performance. Once enough alternatives have been considered, they must decide on the best alternatives and move to the next level of detail or the next area of the project.

The integrated organization must be derived from the product, which is the facility built to enable its occupants to deliver value in some way. The best way to do that is to apply design thinking to pose the questions of what is the function, structure / form and behaviour in the three domains project teams have to affect outcomes. These are the product, organization and process. CIFE combines these domains with the three design questions into a 3x3 matrix, the Product Organization Process Model (Kunz and Fischer, 2012). Table 1 shows a high-level POP Model for the integrated organization.

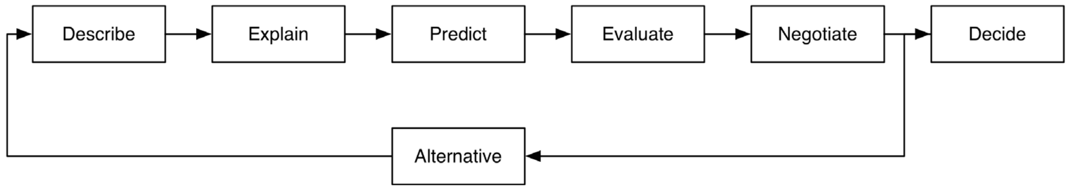

Figure 3. DEPENAD: The integrated team work cycle.

Table 1. POP matrix for a High-performance Building.

QUESTION / LEVER	PRODUCT	ORGANIZATION	PROCESS
FUNCTION	A high-performing building supporting the value desired by the owner.	Integrate builders' and operators' knowledge in design with user needs to create sustainable value. Engage everyone in a meaningful way.	Lead Coordinate Work (learn, predict, decide, commit, act) Decide
STRUCTURE FORM	Right high-performing building made of healthy building materials that enhances, not displaces the environment. All of the features and elements - the scope - promised are built (no compromises for cost).	Engaged Leadership Multi-disciplinary / Cross-functional Teams Direction & Coordination Information Infrastructure Workplace	Target Value Design Integrated Concurrent Engineering Virtual Design & Construction Plan Do Study Act Lean / Pull Production
BEHAVIOR	The building helps rather than hinders people doing their work. Very little grid energy is required. Indoor air quality is excellent. Inhabitants are always comfortable. Little water is used	Good (useable, buildable operable sustainable) decisions are made that advance the project. They "stick." Aligned action produces value More alternatives thoroughly evaluated. Design disciplines develop solutions interdependently, in the same levels of detail. Ways of learning and testing are consistent across cluster teams. No one recreates available information because it's not in a form they need. High frequency and quality interactions to share knowledge.	What is needed is clear and achievable Response and decision latency dramatically reduced Possible solutions can be tested and outcomes predicted with confidence Continuous improvement to produce quality products Waste is eliminated to deliver greater value

INTEGRATED INFORMATION

Integrated information is the backbone and the source of truth, which allows an integrated team to make the best decisions for the project. There are several main aspects, which include consolidating fragmented information, extensive use of 3D models (Staub-French and Khanzode, 2007), a robust IT infrastructure that allows real-time access to the latest information (Teicholz and Fischer, 1994), and an emphasis on making decisions using all available information (Chong et al., 2010).

Sharing information is a lynchpin of the IPD organization. Information must remain consistent across all disciplines, and everyone must have access to all current information, at any time. A significant, but often overlooked, source of project delay is the time and effort spent locating, recreating, or transferring fragmented information. One study found that architects and engineers spend 54% of their time managing information when they work on fragmented teams (Flager et al. 2009). Integrated teams, however, are not impeded by the lack of information availability, caused by poor hardware / software environment or the "hoarding" of knowledge by individual disciplines.

Using building information modeling (BIM), teams can make decisions after analyzing many options, not just on the basis of a handful of options. BIM allows the team to explore many design options rapidly and consistently, discuss how different designs will add value (or not), and how they will affect performance targets. Simulation allows teams to understand the impact of a scenario later down the line, and begin either modifying plans, or prepare interventions to mitigate negative impacts and risks (Eastman et al. 2011). BIM can also help establish an appropriate off-site fabrication strategy, and understand the operability and sustainability of an intentional design.

MEASURABLE VALUE

Currently, most projects engage in early, but often limited, value definition or goal setting. Usually, this is a discussion between the owner and the architect, and the information is rarely passed on to the people working in later stages of the project. In addition, the goals outlined during the early value definition stage are often vague and poorly defined, and there is no mechanism in place to remind the team of goals once work has begun. Moreover, effective and efficient building projects require the definition of measurable performance objectives for all goals, which is typically lacking in traditional value or goal setting efforts.

If a team tracks any metrics at all, they are likely first cost to construct and lost time incidents. Owners are understandably extremely concerned about first cost, however it is a constraint, not a value itself. Time / schedule is the same. Both should be tracked using an established metric. Until this age of powerful and cheap computing, we did not have the ability to simulate and measure alternative designs. Now, we can track not only first cost, but also energy consumption, workflow, natural light, and previously intangible values such as "openness," "connectedness," and other criteria (Flager et al., 2012). Once a team decides how aspects of value can be measured, those measurable values can become design criteria similar to first cost and schedule.

By clearly defining, emphasizing, and tracking the project values, each member of the team is able to make decisions "for the good of the project," because they understand what that means in the context of that specific project. For example, if natural light is a high priority but energy consumption is less important, the team could choose a design with a very high number of windows, even if it resulted in increased energy consumption. Or, if natural light and energy consumption were both of value to an owner, the team could simulate multiple designs highlighting the trade-off between the number, quality, and cost of windows and energy consumption, and the owner could make a highly informed decision between the two (or more) designs.

SIMULATION & VISUALIZATION

Visualization and simulation are the main mechanisms to connect integrated information with the design team. They are the engine of Virtual Design and Construction. By using detailed and accurate 3D models, the team is able to communicate more clearly and effectively with each other, and with the owner (Fischer et al., 2003). Many owners have little or no experience building anything, and the building they build may be the only one they ever do. They are not trained architects and cannot understand complex 2D shop drawings. For most owners, 3D models are much easier to comprehend. Simulation also allows the team to make better predictions by showing how close the design comes to desired outcomes and allowing everyone to see the consequences of their decisions.

Simulations also allow the team to carry multiple design options forward for comparison (Parrish et al., 2008). For example, long and short span steel, and precast and timber structural systems could be kept in play along with appropriate mechanical, plumbing, and electrical systems. Distributed and central mechanical approaches, use of space, energy, and natural light can all be calculated and analyzed and the optimal configuration selected.

COLLABORATION & COLLOCATION

To produce an integrated product, a team must learn to share knowledge and information to define alternatives, recommend solutions and then design them so they can be built, used, and operated. People also need an environment that promotes this Garcia, 2002). Because so many integrated work practices rely on collaboration and consistently getting rapid feedback from teammates, it is important that the team is at least partially co-located. On a larger project, team members can relocate to a large open office, often referred to as the “Big Room” (Khanzode et al., 2007). On smaller projects, they spend two or three days working shoulder-to-shoulder in a temporary Big Room or Integrated Concurrent Engineering sessions (Chachere et al., 2004).

By working in close physical proximity with each other, people from many different disciplines are able to have many quality interactions (Chachere et al. 2009). Team members will interact frequently when they work in the same space, not only in cross-functional team meetings, but around the water cooler and for activities after work. They come to understand who is responsible for what. They learn who to go to for answers and help, and they begin exchanging information with the “right” people. The frequency and quality of interactions increases dramatically resulting in problems being solved quickly and effectively.

With education and mentoring on reliable promising, team members can learn to view their interactions from a “customer-supplier” point of view. When they are seeking information or work, they are the customer. When they are being asked to produce information or work, they are the supplier. Viewing the relationship in this way, team members can understand that when acting as a customer, they are expected to clearly state their needs and expectations. Conversely, when in the supplier role, team members understand they need to know exactly what their customer needs and when, i.e., understand their "conditions of satisfaction."

Techniques, such as rapid feedback, producing small batches, and frequent sharing of work-in-progress, allow the team to produce higher quality work faster. For example, an architect working on window design might take a day to build a partial 3D model, and then show it to the lighting team who immediately see that the windows will be too small for the high-efficiency lighting system that they are designing. The exterior architect can then immediately redirect her window design so that it will work with the planned lighting system. In this way, the team avoids spending large amounts of time (and money!) on vast bodies of work that will either have to be scrapped completely, or simply cannot be integrated to work seamlessly with each other.

PRODUCTION MANAGEMENT

If we want flawless execution, we must plan production very well. If we want to plan production effectively, we must do a very good job of scheduling production. If we want to schedule production, we need to know how well we are doing so we can continually improve performance. If we want to schedule production, we must also create a sound plan for what should happen in the Master Schedule. If we want meaningful milestones to steer the project, we must incorporate what we've learned in our continuous improvement process.

1. Execute Work to Produce Value: Value is created by executing only and exactly the work needed by downstream customers. This value focus underscores the importance of defining value holistically with input from all key building stakeholders. A sequential definition of value as project participants and stakeholders join the project will not lead to a process that is as value adding as possible. To do this during construction, all the required elements must be in place: preceding work is properly installed; safety awareness is high and precautions are in place; space is clear; the right sized, trained work crew is ready; the correct materials are at hand; proper equipment is available; information in the form of quality criteria is clear and understandable.

2. Production Planning: Production must be planned each and every day. The last people to plan work, in most cases the foremen, the "Last Planners," meet every day to report what their crews have accomplished and raise concerns about anything that might disrupt the flow of work (Ballard, 2000). All the information they need is at their fingertips. The Last Planners are open and honest with other trades about the issues they are facing, even when these problems are within their own company. It is no longer good enough to say, "I'll do my best." The only useful responses are: "yes, I can get that done" or "no, I don't have what I need, and this is why."

3. Production Scheduling: Production planning can only be done if the people planning production understand the pace of work required to achieve the Master Schedule milestones and agree that they are achievable. They must plan the flow of work so that each crew has sufficient space and time to install its work safely and properly.

4. Continuous Improvement: The Last Planners must know whether the crews are meeting production, safety, and quality objectives. This is the role of metrics for completing work as planned. Once managers and production supervisors see their problems, they need a process to understand root causes. For example, asking "why?" five times can expose root causes. Operations can be improved by doing "First Run Studies" of operations and by asking crew members to redesign them as they watch a video of themselves at work (Ballard and Howell, 1997).

5. Master Milestones: Master Schedule milestones establish the targets for the production scheduling. Working backwards from delivery, the team defines major deliverables for construction, fabrication and procurement, permits, and design. No one should be under the illusion that they are scheduling the execution of work months or even years in advance without any knowledge of actual conditions. The Master Schedule is a living document and must always reflect both knowledge of the product as well as the progress of construction.

CONTRACTUAL FRAMEWORK

A good IPD agreement creates new rules for the new IPD game. It sets expectations and reduces liability for collaboration, which is currently fraught with risk. Rather than prescribe specific actions, a well-crafted IPD agreement uses a relational structure with jointly shared risk and reward to create a system that inherently enables and reinforces collaboration (Ashcraft, 2012). The key parties within this risk/reward structure are bound together through a multi-party agreement that must include the owner, designer, and builder and should also include key consultants and trades, either as signatories to the prime IPD contract, or through IPD sub-agreements.

IPD contracts place authority within the team. Management is a joint activity so that the shared risk is balanced by shared control. This reduces the fear that chills creativity, and places decision-making in the hands of the best informed individuals – those closest to the actual work. By requiring major decisions to be made jointly, decisions stay aligned to the project goals, and are supported and understood by everyone. IPD contracts also limit liability among team members, which allows them to feel secure sharing information and work that is still in progress. Without liability limitation, fear of litigation quenches vital information exchanges and drives team members back into their "information silos."

A traditional contract approach largely ignores creating structures and relationships that promote overall project success. Using guarantees, penalties, and risk transfers, these mechanisms attack the symptoms (poor quality, high cost, and excessive duration) without addressing the fundamental causes of poor performance. They excel in assessing liability, but do very little to avoid the risks. In fact, the focus on liability assessment and risk transfer reinforces individualistic behavior and exacerbates the dysfunctions that created many risks in the first place. In addition, because these agreements are made between two firms, rather than amongst the entire team, they reinforce individual rather than project optimization, lock up information, and hamper communication flows.

By itself, the IPD contract accomplishes little. Just as a skeleton creates the potential for motion by providing a structure, an IPD agreement creates the potential for success by providing structures that allow the other elements of IPD to function effectively. And, like a skeleton, if the contract is incomplete or malformed, it can limit project performance. But, correctly designed and layered with integrated information, integrated teams, and integrated processes, it becomes a strong and flexible tool for integrated projects.

CONCLUSIONS

Given the demand for facilities with a high performance in economic, environmental, and social terms, we suggest a switch from the fundamental strategy of decomposing a project into smaller parts to the fundamental strategy of integration. We foresee that individuals and firms that make this switch will have a more rewarding work experience because it will likely be more productive and effective. As was highlighted in this paper, the integration approach requires a mix of organization and process design and management coupled with modeling, simulation, and visualization technologies that are quite different from today's common project design and management practices. The Simple Framework describes the best way we have found to integrate to consistently deliver high-performance facilities.

ACKNOWLEDGMENTS

We are indebted to the members of the CIFE community – its faculty, students, and industry collaborators – for the vision and concepts presented in this paper.

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