Developing Competitive Systems

Executive Brief
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Turning Technology Into a Competitive Advantage for the Built Environment

Transforming practices for delivering a smarter built environment

What are smarter products?

Smarter products are …

… instrumented

The potential of products is taking off with the incorporation of new technologies (for example, sensors, actuators, cameras and GPS systems) that provide individualized context and let you measure, sense and see the exact condition of just about everything.

As you walk down the street, your smart phone notifies you that your lunch appointment is on the left 100 feet ahead and that your client is within 400 feet of the cafe as well. You get to the front door of the cafe and check in with the hostess who notifies you there will be a five minute wait for your table and asks if you would like a sun tea spritzer since that is what you ordered last time your were there. Your client arrives and you inform him of the wait and ask if he would also like a drink. This is his first time at the restaurant and the hostess asks if he would like to register for their preferred customer rewards program. He accepts and with a simple text message his acknowledgment is registered. All this interaction took place in less than three minutes, and the level of service is significant. Technologies such as global positioning systems (GPS), customer preference databases, encrypted financial transactions, order management as well as service delivery notification systems riding on smart cellular and wi-fi networks made all this possible. And this is using current technologies in place today.

… interconnected

Mass production no longer dictates how people use specific products. Instead, when a collection of smarter products is interconnected into an ecosystem to work together, it creates experiences that can mold to the specific preferences of an individual's daily work and personal life.

This example is a small example of how businesses around the world are seeking to revolutionize mundane, everyday tasks with integrated technologies. Rather than solutions as single element solutions, now we are thinking of solutions that are integrations of components into a greater whole. Systems that can be adapted to meet the personality and requests of individuals as they move through their daily activities. Such systems are supported by open communication systems and standardized data protocols that are delivered in realtime. the application possibilities in automotive, building environmental, service delivery, repairs and even logistical delivery are just beginning to be examined. As integrated systems the possibilities of increased efficiencies is significant.

… intelligent

The array of products used to deliver an experience can now get to know you or the problem you are trying to address. It can respond to change quickly and accurately and get better results by predicting and optimizing for future events.

Figure 1. Smarter products are extremely pervasive and demand a level of intelligence and integration previously unheard of.

A new layer of complexity

Because smart buildings are more complex they require a new paradigm for how they are designed. Think of the new sustainable building as a platform used to generate electricity, adapt personal productivity environments to occupants needs, shut down unused occupant areas automatically, provide rolling security envelopes around sensitive personnel and change the absorptive characteristics of the building skin to optimize solar power generation, just to mention a few possibilities.

As a comparison,

- *a luxury car often represents an investment of of almost $1billion in software and hardware investment.* [1]
- *A modern frontline jet fighter has over 1.7 million lines of software code embedded into the aircraft's operation.*

In the near future, smart buildings will require more thought as the structure acts as a set of "bones" to carry an ever evolving set of systems that adapt to effectively optimize the environment of the building both internally and externally.

Sustainability will be measured in terms of total net carbon reduction, energy output as a function of the building's total life-cycle.

Why smarter products? Differentiation

The six billion people on the planet all have unique needs, desires, hopes and approaches to getting things done and enjoying life. As we deliver buildings and environments that are more than just enclosures for comfort, but platforms for increasing personal productivity we will be adapting the surroundings to meet their needs. As an added bonus, we also create the possibility of environments that are more efficient as well.

Businesses and consumers are now craving personalization and integration of the environments around them everyday - products that create a custom environment for them without effort, adapting to the context of their activities, increasing their comfort, productivity and enjoyment of their experience. Manufacturers and service providers are driven to look for new, innovative ways to provide these services in a unique and different way.

The nature of smarter products

Smarter, adaptive products force designers and manufacturers to rethink the very nature of their offerings. No longer can there be an array of single-purpose devices to meet the demands of a consumer, now integrated platforms that can be easily reprogrammed and repurposed are the baseline expectation. These smarter products demand more thought and design than ever before. To achieve these expectations new ways of thinking must be employed.

Systems of systems

As if designing and building complicated systems weren't hard enough, many of today's products, such as cars and planes and buildings are, in fact, systems of systems. Features are no longer isolated within individual products and are instead delivered through integration with back-office business processes. For example, in-vehicle security system vendors can now provide emergency services and can alert first responders with accident details gathered using vehicle sensors and passed through the vehicle's security system to assess the severity of automobile crashes. Buildings are just beginning to see the possibilities of being a smart platform to deliver efficiency and comfort.

Emerging environmental systems

As electro-mechanical devices become more miniaturized, energy efficient and easier to build, the enclosures we construct will have the ability to sense how to blend both the exterior energy inputs, interior systems conditions and human activity within the enclosure to create the optimum environment needed. Buildings will go from the highest consumers of energy to a producer of energy. Sensor technologies and micro-energy processors will create the reality of energy being trapped within a building and being used over and over again as opposed to the common single pass energy use systems traditionally used.

Smart buildings require standards for common tasks of data exchange and communication so as new enhancements become

available modular upgrades of components, rather than entire systems are deployed. Since most of this technology is communications based, current standards for mainstream products should be implemented to allow for easier upgrades and deployment.

Mechanical aspects are becoming commoditized as product value shifts to software

Today, the hardware that previously differentiated products has largely become a commodity, and it is becoming increasingly difficult to differentiate products based on electronics alone. Only a few years ago, an MP3 player was just that- a device that played MP3s. Now MP3 players must not only play music but also host music libraries, stream video, run applications, support messaging and offer games. And devices that cannot be easily updated with new functionality quickly become obsolete, destined for a local recycling center.

Similar progress is being made in building monitoring and controls systems. Where previously an occupancy sensor drove only a single lighting circuit, now we can use that same sensor to drive an entire room environment. When we pair several different sensors we can achieve an economical daylighting harvesting system which can lower energy demand from 10% to 50% and increase comfort and productivity of the people using the space.

Hydraulic hybrid delivery vehicles

The demand for a high-efficiency urban delivery platform was realized by the Eaton Corporation. They developed a hybrid system using hydraulics and mechanical systems and electrical control systems orchestrated by a sophisticated software system. These next generation delivery platforms are truly an integrated system of parts not assembled in this fashion before.

Embedded smart control systems give this platform the ability to deliver efficiencies that result in companies like UPS to be able to reduce their carbon dioxide ($C0_2$) emissions by 40 percent and achieved a 60 to 70 percent reduction in fuel consumption, according to the Environmental Protection Agency.

Manufacturer or software company? The blurring line

The reality is that product manufacturers are now also becoming software companies, infusing the technological capabilities of electrical, mechanical and software components into a new generation of innovation. Unfortunately, many companies simply do not have the skill sets, resources or development platforms necessary to build and integrate the intelligent software that is needed.

The traditional delivery method of individual design, development, fabrication and assembly teams no longer meets the needs of a holistic product delivery method. Team integration is required to manage the complex interactions required to deliver a new generation of projects and products. But this is easier said than done. Changes made will affect decisions made by multiple teams, leading to complex project management testing and change control.

The next generation built environment must ensure all systems respond to open systems requirements if the back-end IT and management systems have a chance to work. Teams must recognize the importance of open communication methods and break down the traditional silos between technologies, competing companies, between vendors and even between governments.

Smart buildings can reduce the energy demands by as much as 80 %. NEXT 10, a non-profit educational organization, indicates that current building technology could reduce their energy requirements by 30% by raising their levels of insulation to current standards and by using more efficient lighting technologies by another 20%.[7]

Traditional workflows result in inefficient results. The basis of these workflows have been outmoded due to the new integrated vertical development cycles needed to deliver projects today.

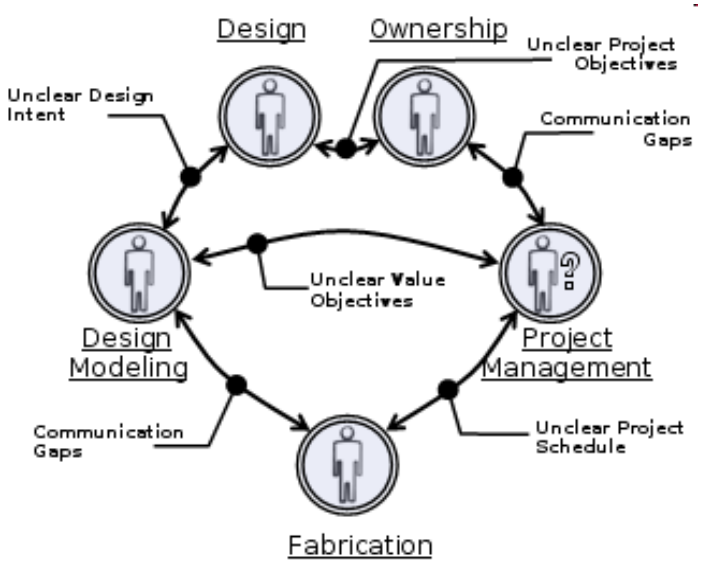

Figure 2. The gaps that exist between vertical development silos can undermine project development, change management and requirements mapping.

An encompassing view

Understanding how the smarter products fit in context of their ecosystems can offer businesses:

- *Better understanding of over-all system requirements and constraints.*
- *Help in the design process by focusing on the interaction of the system with the surrounding environment.*
- *Aid in avoiding errors through explicit design and organizational decisions that, when left implicit, are often the cause of errors.*

Implications of an inefficient approach

Failure to adapt to the new challenges for delivering a more effective built environment will significantly affect a community's competitive advantage in the larger economic market. Smarter project delivery that brings highly efficient projects to market means today's innovation will allow for the survival of competitive organizations tomorrow. The risks of inaction are significant:

- Inconsistent representation of design intent across disciplines
- Adversarial relationships between all parties to protect their individual interests at the expense of others
- Loss of value through increased time and materials needed to complete the project due to lack of effective communication and fabrication techniques
- Lower building value results in lower Return on Investment for owners.

Best practices for integrating smarter products

Explicit dialog communication focuses energy and resources toward value-driven solutions.

As we've seen, remaining competitive in the current marketplace requires significant changes in how value is delivered in today's projects and products transforming the process from lowest first cost to innovative features insuring best value long-term value. For many new and emerging products in the AECO domain, products and building systems that have embedded software control and management provides a completely new value proposition from the mainstream product offerings. Development of these products have moved from a focus on graphic documentation systems to data-rich model built on the basis of design so fabrication transforms much of the development effort from a singular engineering effort to a collaborative effort of marketing, systems development, engineering, sales and field installation support.

And this value, in turn, is driving changes in the way these products are built—from a focus purely on cost to a focus on innovation with software as a major differentiator. Because of these emerging differentiators, the business models are shifting from localized development efforts to to globalized development.

In fact, an Aberdeen Group study in 2008 shows that those companies whose products include more software in the product mix do better than those whose products are more mechanical or electronic.[2] The challenge to deliver smarter products requires companies to rethink how they approach product development from an isolated departmental approach to an inclusive systems level approach. Building design and construction is following a parallel approach. Traditional design done in a vacuum cannot deliver the ever-increasing demands of more energy efficient buildings that last longer, are easier to maintain with fewer personnel and create more lasting capital value to Ownership.

Classes of Owners

1. **Institutional / Governmental**
   Large RE holdings with significant capital investment.
2. **Corporate**
   Larger companies that rely on RE improvements a part of their service or product delivery
3. **Property Management / Investment**
   Companies that specialize in Improved RE investments, often spread over large geographic areas.
4. **Individual Property Owners**
   Similar to Corporate Owners but on a smaller scale.

Management

Proper management of complex projects can have a dramatic effect on the value delivered to an Owner. To achieve this value the delivery team must focus on the constituent parts of the entire design. In fact, each major contributor should act as a CEO of a product component of the larger whole, bearing the responsibility and authority for the integrated response, fabrication, installation and support. As each CEO sees themselves as part of a greater whole, contributing value to achieve a greater encompassing goal, their value increases and hence their responsibility to achieve that value for the entire team. It is an idea of investment rather than a simple transactional event where a standard part is delivered without understanding the impact of the part on the whole. This relationship is the basis of Value-Driven Project Delivery.

Successful integration of the constituent parts delivers value to owners and creates more reliable revenue for the producers and integrators. This integration process places value on the processes and products that respond to the goals of the project. When those goals are met, significant value is realized. During this complex process of integration, there is a cyclic evaluation process going on to validate the creation of cost vs. delivered performance. Where

that result is positive, positive value is created. When the anticipated value is not realized the integration team evaluates how to change the design response to achieve the desired results.

Varied Ownership needs and goals demand flexible system responses.

Owners at different levels will have different expectations and business value drivers. There are a few common drivers that are emerging in today's changing economy. All owners, whether they are in the Public or Private sector are scrambling to reduce operational costs, especially in markets where increased funding or revenue is not likely to offset increasing energy and water costs. Increasingly occupant comfort is becoming a recognized requirement. For some owners this is driven by apparent increased efficiency of employees in more comfortable environments, for others it is being driven by demands from prospective tenants as a perceived benefit. In any event, we have a seemingly divergent set of expectations to deliver more functionality and performance for less cost.

Where these value propositions cross, increased value can be derived. When there is alignment of business values with economic forces and supporting technology, a significant opportunity exists to capture that value. This is the challenge of the new AECO industry. No longer can we deliver products that deliver a minimum enclosure that keeps out the basic elements. Now we are called upon to deliver that basic requirement in a more pleasing manner and at a higher performance level over a longer building lifespan.

Success for everyone depends on each contributor understanding how their work delivers value to the overall project. Clear communication between the parties is crucial to assure timely and accurate responses by everyone. The language barrier is often an impediment to clear communication in the AECO industry.

The design and construction domain is the largest component set in our economy that has not had any significant increase in productivity since the US Department of Commerce began compiling efficiency data in the early 1920's.

Westinghouse Rail Systems Australia

Marketing its rail signaling and control solutions across southeast Asia, Westinghouse Rail Systems Australia (WRSA) needed to design its offerings to comply with a number of global and national safety and reliability standards. As an added complication, the business had to deliver technology innovations that were backwards compatible with previous equipment, as few customers wished to update their entire rail signal infrastructure.

WRSA deployed a uniform requirements and configuration management solution that enables designers from across the company (regardless of location) to move seamlessly between projects without interrupting development schedules. Moreover, the business can leverage this design flexibility to more easily tailor its offerings to support the unique needs of each region in which its solutions are sold.

Ensure that customer requirements are met

As we strive for success in delivering the requirements identified by owners, users and maintenance, there is the requirement to understand how the product will operate as a system, or as part of a larger system. Understanding functionality in the context of a system will produce a set of requirements to determine what the system does and how it accomplishes it.

Before the advent of online collaborative capabilities available today, design operated in isolation, with only formal communication as the hand off from one development process to another occurred. One set of perspectives shaped the content and presentation of requirements derived by analysts, and then they passed those on to technical design professionals who have used 2D and 3D documents or models to capture the design intent and fabrication requirements. Fabrication takes these documents and begins to implement them finding gaps in implementation or functionality.

Problems with this traditional approach are multiple. Each time a hand off of information occurred, a different set of language filters were employed for each party. Analysis, design and fabrication all have their distinct languages, jargon and expectations and few of these are understood by their neighbors in the process.

To add to the confusion as we increase the capabilities of products and they take on more and more integrated functionality, the level of understanding between all the members of the process chain become more complex and demanding. Decisions regarding implementation of functional requirements and project objectives require more input from a full array of participants from designers, engineers, legal teams, marketeers right through to suppliers and distribution chains. Often the full impact of a decision is hard to judge without a more holistic view.

Océ

A leading international provider of digital document management technology, Océ designs advanced software applications that deliver documents and data over internal networks and the Internet to printing systems and storage archives. Wanting to add the fastest cut-sheet printer in the world to its offerings portfolio, the business ran into a number of design challenges in developing a control system that could accurately track the dozens of sheets of paper that would be simultaneously running through the printer.

The business employed a model-driven development strategy to decompose the complex printing system into smaller, more easily designed subsystems. Moreover, by coupling the object orientation and inheritance features of model-driven development, Océ has been able to heavily promote component reuse within the new printing solution. This design strategy helps to shorten time to market, increase efficiency and improve overall quality.

Modeling, the new paradigm

New paradigms are being developed to support this more complex problem set. Software advances have given us tools to model a myriad set of variables from risk assessment to process management to physical design and fabrication models right through the entire fabrication set. Each modeling tool provides another view of the problem. Taken together as a whole, these models reveal the weaknesses in setting requirements, defining solutions, implementing solutions and delivering services and all the while measuring value and quality as the process evolves.

The virtual world of modeling is far less expensive to navigate, change, and improve as a set of integrated components. Models allow for simulation of these proposed changes and methods to determine the effects of those changes. The time to apply analysis and results evaluations in the virtual world give the entire team the opportunity to raise the quality of the final product and often realize new functionality while staying within the determinants for the project.

With a detailed system design in place, a delivery team can begin to design the components of the environment desired, beginning with the component elements of the design in their physical forms as well as the processes to be executed by software. The marriage of the physical, mechanical, communications, data and software control domains in an integrated process helps teams:

- *Ensure that requirements (along with their intent) are met.*
- *Devise tests for design compliance, fabrication, assembly and software development.*
- *Generate software code automatically to implement specific functionality.*
- *Simulate desired outcomes to validate functionality against value derived.*

When we evaluate these complex solutions as a collection of systems acting together in concert, performance is revealed in a way that clarifies how the interactions of systems work that are obscured when looking at the larger picture. Tracing the path of interactions within these complex events removes much of the risk of error and allows for much richer solutions to appear.

BAE Systems Australia

BAE Systems Australia is a designer of integrated military systems and support solutions for the Australian Defence Force. Previously, the organization had been unable to effectively coordinate the efforts of its hundreds of geographically dispersed developers, resulting in duplicated efforts. The business was unable to even establish corporate best practices for design staff since requirements management tools varied between teams and projects.

The organization implemented a unified requirements management solution to support requirements analysis on all customer projects, as well as proposals. Designers can now maximize requirement reuse across all phases of development, yielding faster bug resolution and shorter time to market.

Change, the ever-present constant

Despite the best efforts of design teams, changes in a project will occur. Design solutions and values shift, new needs are discovered, priorities for functional elements shift seemingly leaving the only constant to be change itself. Understanding the effects of change within a complex design set can be challenging at the least and is often overwhelming. In the past, we delayed dealing with possible change until the last possible minute, hoping many of the issues surrounding a decision would be revealed and make the solution apparent. Often this method resulted in an inefficient and compromised solution. Wasted energy and materials were often the result and many times the final solution required some significant rework to accomplish the compromised solution.

Modeling can provide a means to under the impact of change. Trade-off analysis is much easier to conduct when scenario analysis shows the most probable outcomes of different decisions. Final value can be derived when comparing and contrasting various data sets. Changes in suppliers, installation order or methods, even optional materials selection can all have significant changes in results of different scenarios. Balancing the various costs against the benefits, while assuring all the project goals and functionality are met, exemplifies true value-driven project delivery.

Multi-discipline integration is a key element to successful change management. With the ability to collaborate and share information in a common format, changes can be made more effectively with the knowledge of the end result available before any physical operations have begun. The foundation of this multi-discipline activity is a shared commitment to a common goal, a common language of activity and risk sharing spread across the entire team in an equitable way.

Elevate Project Delivery to a Strategic Business Initiative

Companies well versed in traditional delivery methods have not necessarily adjusted to the increased demand for more efficient project delivery. In particular, they have not adopted good communication technologies and supporting collaborative and modeling software.

Collaborative communication between design, delivery and operation groups, increase visibility, remove silos

Earlier we mentioned the necessity of clear communication to achieve the greatest value through the entire development and delivery process. It is apparent that many traditional domains of expertise have developed very sophisticated languages and processes that serve each well, but becomes a babel of noise when viewed by others outside their areas of expertise. In many cases, even arriving at a common understanding of a common set of goals and principles for a project is a difficult problem to overcome. With so many different filters of experience and perspectives for a single statement, is it any wonder that projects achieve any level of success at all.

What previously seemed to be a simple enough problem, has now become a "wicked problem" which is more closely tied to problems which have "incomplete, contradictory, and changing requirements; and solutions to them are often difficult to recognize as such because of complex interdependencies."[8] Often when working with these problems other similar problems are exposed. New tools are required to discuss and parse the requirements of these problems, since their solutions are multi-variant and always without a final definitive solution that fully addresses all the component issues of the problem.

In an effort to manage this complex set of issues H.J. Rittel proposed a framework he called "Issue Based Information System (IBIS) which enables groups to decompose into questions, ideas and arguments, to better deal with wicked problems. A byproduct of this method is a single language of understanding and commitment to a set of values is derived for the single purpose of continuing the dialog to arrive at a solution and then evaluate the pros/cons and potential consequences of the alternative solutions. The importance of Issue Mapping is the breaking down or decomposition of the issues in a way that everyone connected with the problem / project understands their context.

Another element of an effective communication protocol is to have a common platform that is inclusive of all the formally siloed professional services. When a common platform for expressing design, engineering, fabrication, assembly, delivery and maintenance exists, all these expertise domains have a chance to reveal and bring into play their unique values as they impact the overall project delivery. Currently there is a diversity of modeling

software for various domains which collect, analyze, and predict possible results. No one single solution will capture the unique and precise information in a single environment, nor should that be a goal. Rather, the ability to share the results of the analysis in a common data and communication format would be helpful for all disciplines.

One such example is the EDI / xml document format and communication protocol which has been used for decades in the manufacturing and distribution worlds. International standards exist for transmitting orders, specifications, payments, confirmations and other supporting commercial transactions between very diverse software products. The built environment has been promulgating various standards since the 1980's for graphic entity formats, the most recent being the International Foundation Classes. This relatively new format seeks to combine the elements of graphic object definition along with attendant data and parametric values of the component objects. Much work is still needed to get this format to work within that single domain of the built environment, but it will need to expand to be able to adequately communicate with the already existing EDI / xml formats of commerce if true integration is to occur.

Model-driven project development

Previously we identified there are many software modeling tools and methodologies available to assist with the integrated project delivery solution. They include business process models, data and communication network transmission simulation, component design and discrete manufacturing design to fabrication links as well as sophisticated building modeling software. All these work on different environments and have different human and machine interfaces.

The one thing they all share is a common attribute to analyze models from various perspectives. Analysis of a virtual scenario is one of the tremendous strengths of virtual modeling efforts. Rules-based tools that allow performance testing of modeled solutions can provide the required information needed to evaluate various solutions and their contributed value as measured against the stated goals of a project. Analysis tools very often represent their results as graphic summations of sizable data sets to ease the interpretation of the results of the analysis rules.

When comparing the results of various combined results of elements of a design, business process and physical assembly changing one element of any one of the others can have significant results on the process flow both upstream as well as downstream. For instance an advantageous spot price on a building material could have resulting implications on designs and future availability of compatible replacement parts when maintenance is required. In that instance, additional costs to evaluate, redesign adjacent components and verify if the future parts will be available, could create a net negative value on the project.

Governance and measurement

Often an over-looked aspect of any project is the ability to measure and govern how well the process is performing. In fact, governance and the attendant conversations about focused work is often more of a driving component for productivity than raw computing power. When improving productivity it's often helpful to use a four-step process to measure reliability and capability improvement.

1. Determine and set design, environmental, construction operations and capital value objectives.
2. Determine the solution possibilities
3. Accelerate solution adoption through collaborative dialog
4. Review and communicate objective attainment.

Using a measured improvement framework enables a cyclic improvement for transformation of results, accelerates adoption through readily available components, provides flexible feedback on the business, design and construction process and finally captures industry experiences in continued adoption.

Since the level of the projects we are dealing with are by nature wicked, no single solution will likely be repeatable in its entirety, but portions of each solution will shed light on possibilities of continuing efforts. Governance may provide a structure to measure progress, however the resulting systems will mature as more and more vertical integration is achieved in each effort.

Toward a competitive advantage

In the last 30 years the manufacturing sector has become more efficient and innovative by harnessing many of the ideas presented here. Likewise the software world has adopted many of those value propositions and business processes. The design and construction domain is the largest component set in our economy that has not had any significant increase in productivity since the US Department of Commerce began compiling efficiency data in the early 1920's. The overwhelming consumption of energy and water that the built environment consumes is the largest single component in our energy economy. As the largest consumer and least productive contributor to our economy, we have a long way to go to match other sectors of our economy.

On the bright side, even creating savings by increasing lighting and envelope efficiencies in the residential and commercial sectors over the next 10 years would bring about a significant savings that could likely delay the need to expand our electricity generation capacity in the short term[7]. But the delivery cycle needs a significant overhaul to allow the integration of solutions into larger systems. Inter-

disciplinary teams with clearly defined goals and objectives value-driven project delivery can begin to eliminate more waste and create more efficiency and long term value in the built environment we finance, design, construct and maintain.

We invite you to join us in the effort to deliver more efficient buildings through collaboration and smart design.

Endnotes

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