
Implementing

# Virtual Design & Construction Using BIM

Current & future practices

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ROUTLEDGE

# Implementing Virtual Design and Construction using BIM

*Implementing Virtual Design and Construction using BIM* outlines the team structure, software, and production ecosystem needed for an effective Virtual Design and Construction (VDC) process through current real-world case studies of projects both in development and under construction. It provides the reader with a better understanding of the successful implementation of VDC and Building Information Modeling (BIM), and the benefits to the project team throughout the design and construction process. For readers already familiar with VDC, the book will provide invaluable examples of best practices and real-world solutions.

Richly illustrated in color with actual VDC documentation, visualizations, and statistics, the reader is shown the real processes undertaken and outputs generated when working on high-profile building information models. Online animations, interviews with practitioners, and downloadable templates, forms, and files make this an interactive and highly engaging way to learn a crucial set of skills.

While keeping up with current industry practice is a minimum requirement, this book goes further by helping practitioners prepare for the next level of virtual design and construction. This is essential reading for project managers, construction managers, architects, design managers, and anybody with a role in BIM or virtual construction.

**Lennart Andersson** is the director of Virtual Design and Construction (VDC) at LiRo. He studied engineering in Sweden and received a master's degree in architecture in the USA. He is a licensed architect with sixteen years of experience applying virtual design and construction methodologies on a wide variety of projects. Lennart is spearheading the firm-wide adoption of VDC at LiRo. Examples of projects he has been involved in are East Side Access, City Point Brooklyn, New York Public Library, and a number of other large-scale projects in New York City. He is a visiting professor at Pratt Institute in New York, where he teaches an advanced, collaborative VDC studio between architects and construction managers in partnership with the New York City Department of Design and Construction. He has hosted several seminars covering advanced VDC use in design, construction, and operations.

**Kyla Farrell** worked as a VDC project manager at the LiRo Group from 2012 to 2014. Prior to LiRo, she was employed by Gehry Technologies, Zaha Hadid Architects and SHoP Construction, where she developed and managed parametric 3-D models for the design, fabrication, and coordination of complex projects. Kyla received her first degree from Stanford University and holds a master's degree in architecture from the Southern California Institute of Architecture. She currently works as a software engineer in the San Francisco Bay Area.

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# Preface

Information technology is rapidly connecting all corners of the world, dissolving physical barriers and enabling previously impossible global interactions. As per Moore's Law,[1] computer hardware is evolving at a breathtaking pace; a mobile phone today is in some ways more powerful than a building-sized supercomputer was some 30 years ago. Furthermore, cloud computing has opened up new forms of communication and channels for sharing information around the globe. Cloud computing provides an abundance of available processing power, which has an enormous impact on processes and workflows across all areas of human endeavor.

We are entering the era of the Third Industrial Revolution. Technological innovations in manufacturing such as robotics are radically changing how products are made. Manufacturing techniques such as 3-D printing make it possible to create products locally and on demand, rather than stockpiling or shipping them across the world. Social networks and the interconnectedness of information technology are fostering new ways of thinking and working collaboratively. Crowdsourcing is making it possible for groups of physically disparate people to team up and work on projects and collectively arrive at solutions. It is more beneficial for individuals to share rather than "own" information, as the expiration date for some knowledge is drastically shorter now than in the past. Continuous learning must be incorporated into everyday workflows to stay on track with current progress.

## GLOBAL PERSPECTIVE

As we enter an age in which many more people can produce drastically more product than was previously possible, we face enormous challenges in tending to the limited resources of this planet. Around the world, we are already depleting the resources we depend on.

The Industrial Revolution grew out of a view that we have infinite resources at our disposal, so the process of design focused solely on manufacture and usage. Very little thought was given to the impact of production on the environment, or what happens to something once it has served its purpose. Today, a different way of thinking must prevail; we need to put what we do into context and realize the interconnectedness of the systems in which we operate.

## BUILDING INDUSTRY

The global building industry is one of the largest industries in the world and will grow from approximately an $8 trillion industry in 2013 to a $12 trillion industry by 2020.[2] Yet, building construction is still quite often a low-tech environment that can be extremely inefficient and wasteful. Indeed, it may be the only industry that has actually declined in efficiency over the past 20 years.

As building requires an enormous amount of resources, the industry has substantial effects on the environment. This book addresses the rapidly evolving technological tools that will make it possible to understand and change how things are built, and to streamline construction processes and minimize waste. The tools themselves will not solve our environmental quandary, but they enable us to visualize and solve complex problems. These tools bring transparency to the industry and expose the myriad interconnected issues involved in the building process. The industry can dramatically reduce its amount of waste by efficiently utilizing virtual building technologies.

## BUILDING VIRTUAL

This book illustrates how technology can be successfully applied on a range of projects from an academic and theoretic perspective, and demonstrates how Virtual Design and Construction (VDC) actually interfaces and functions in the real world through case studies in New York City. The case studies included here are supported by reference chapters, which describe the tools and settings that help ensure the success of a VDC project.

As we are constantly developing VDC tools and workflows, please refer to our website for the most up-to-date examples and files at www.buildingvirtual.net.

## ACKNOWLEDGMENTS

We would like to thank everyone who helped us on the projects described in this book, especially LiRo's CEO Luis Tormenta for believing in our department from the very beginning. Additionally, our colleagues Michael Bailey, Michael Burton, Vikas Wagh, and Vincent Valdemira who provided us with valuable industry knowledge, time, and resources. Our clients also deserve a big thanks, including Mark DeBernardo at MTA Capital Construction, for being our advocate when we started at East Side Access. Many thanks go out to Arta Yazdanseta and Harriet Markis for giving valuable feedback on early book concepts. An additional thanks to Brian

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Last but not least, we would like to thank everyone on the LiRo VDC team integral to the success of these amazing projects: Fernando Vazquez, Scott Blond, David Deiss, Izzet Keskintas, Aditi Patel, Jorge Berdecia, David Wu, and Brian Szeto.

## NOTES

1 Moore's Law is named after Intel co-founder Gordon Moore, who predicted in 1975 that every two years the number of transistors in chip elements will double. So far, this prediction has proved to be true. Stephen Shankland, "Moore's Law: The Rule That Really Matters in Tech." CNET, October 15, 2012. Web. December 23, 2014.

2 David R. Schilling, "Global Construction Expected to Increase by $4.8 Trillion by 2020." Industry Tap. March 08, 2013. Web. November 10, 2014.

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# 1 Introduction

Disruptive new technologies are transforming all facets of the built environment. Virtual Design and Construction (VDC) is the implementation of these technologies and processes. Understanding this emerging field is essential for all professionals working in Architecture, Engineering, and Construction (AEC).

The success of VDC depends not only on technology, but on the skills and knowledge of people who initiate, design, construct, and operate projects using a wide variety of professional tools. The ambition of this book is to communicate how powerful new tools significantly improve the process of building, as well as the quality of resulting buildings.

The AEC industry refers to much of what we discuss here simply as Building Information Modeling, or BIM. We find "BIM" to be an inadequate description of the workflows we are developing as VDC professionals. For the purposes of this book, the result of BIM or "BIM model" will be referred to simply as an "information model." For activities incorporating use of an information model, we use the terms VDC process (or methodology), VDC service, or VDC product. VDC processes are workflows that incorporate the information model and integrate previously disconnected aspects of design and construction. VDC processes seek to apply new technologies to the AEC industry and link all the work being done by the project team into the information model. The information model acts as a hub. VDC services are specific services unique to VDC, such as clash detection, 3-D scanning, tracking, or information model authoring. A VDC product is the deliverable resulting from a VDC service, such as a point cloud, a systems coordination model, database, or a constructability logistics animation.

While the concept of BIM has its roots in the early beginnings of computer technology, it was not until the personal computer became powerful enough to drive the data and graphics in real time that 3-D models became a useful tool. An information model simulates the geometry and data of an environment, unlike Computer Aided Drafting (CAD), which is merely a representation, like a drawing on paper. The information model is a virtual, geometrical, spatial relational database. It keeps track of data as it relates to specific geometry and location. Many types of data can be linked to a virtual object, and there are many possible ways to use and analyze the data contained in the model.

An information model is powerful because it allows all of the data surrounding a building project to be centralized into one ecosystem that all participants can share. This centralization mitigates problems associated with the fragmentation of data inherent in the traditional design and construction process. For example, someone viewing color-coded 3-D models instead of black-and-white line drawings gains a much better understanding of the project at hand, as relationships between different components are more clearly visible. Using information models thus minimizes the risk of misunderstandings and subsequent conflicts.

The case studies in this book are written from the perspective of our experience working in the VDC department within the LiRo Group, a Construction Management, Architecture, and Engineering firm headquartered in Syosset, NY. LiRo is a professional, full-service design and construction management firm ranked among the nation’s Top 20 CM firms by Engineering News Record in 2014. The VDC department operates out of its own office in Manhattan. In addition to the VDC group, LiRo’s current workforce of over 650 personnel includes licensed professional engineers, architects and field staff experienced in design, pre-construction, construction inspection and supervision, CPM scheduling techniques and computerized logging and document control systems. The staff also includes experienced value engineers, certified cost estimators, and LEED accredited professionals. The construction management team enlists in-house environmental, structural, traffic, and civil engineers, hazardous material specialists, PLA consultants and database developers, among others, to respond to any technical need that may arise on a project. From our vantage point in the VDC department, working with LiRo’s full spectrum of designers, engineers, and constructors, we have a deep understanding of how the various processes of a building project relate to each other.

The construction manager’s (CM) main role is to ensure that the intended design is built in the best possible way, at the lowest cost and in the most time-efficient manner. The tools a CM uses apply mostly to means and methods, such as planning and tracking the construction of the project. A CM ensures that all parties understand their scope and responsibilities through contractual documents. Specific services rendered include specification authoring, sequencing and scheduling, cost estimating, constructability review of the intended design, creating staging plans, tracking and reporting progress, enforcing site safety, quality assurance and control as well as cost-related tasks, such as value engineering and administration. All these services can be greatly improved with VDC processes. The CM might actually be one of the greatest beneficiaries of VDC, as the transparency it affords helps the CM understand and monitor every aspect of the project.

VDC will only continue to expand as a discipline, becoming a further integrated part of the AEC process.[1] New technologies and innovations are constantly being devised to address the many inefficiencies in current professional practice. As VDC professionals, we are interested in the rapid advances being made in the development of new technologies that facilitate a bidirectional link between the real and the virtual, providing a platform for better decision making. 3-D scanning, 3-D printing, sensors, prefabrication, automation, and robotics are among the many exciting innovations being developed. At its core, VDC ultimately seeks to bridge the expertise gaps between design, construction, and operations; to realize facilities that are dramatically less wasteful both in assembly and usage; and to create buildings that function to serve their occupants throughout the complete usage lifecycle.

## NOTE

1 Forty percent of US owners and 38 percent of UK owners expect that more than 75 percent of their projects will involve BIM in just two years. McGraw Hill Construction, Marketing Communications, "U.S. and U.K. Building Owners Expect to Increase Their Involvement with BIM in the Next Two Years," Market Watch. October 13, 2014. Web, October 24, 2014.

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# 2 The Practice of VDC

VDC is an interdisciplinary practice in which data is centralized, typically within a 3-D information model, allowing for increased efficiencies and deeper project understanding and analysis. VDC is a shift from mere representation of project information as in a 2-D design process to detailed simulation, from a linear design and construction process to a concurrent process with live feedback loops. Implementing a functional VDC practice requires an understanding of the building process, structure and professional culture both at the project and enterprise level.

VDC processes are workflows that incorporate the information model and integrate previously disconnected aspects of design and construction. VDC processes seek to apply new technologies to the AEC industry and link the work done by the project team to the information model. The information model acts as a central hub in the VDC workflow. VDC services are specific services unique to VDC, such as clash detection, 3-D scanning, tracking or information model authoring. A VDC product is the deliverable resulting from a VDC service, such as a point cloud, a systems coordination model, database or a constructability logistics animation.

VDC services can be utilized throughout the entire design and construction process. If VDC services simply run parallel to traditional workflows, they don't provide the optimal benefit to a project. VDC services must be integrated into the traditional trades and everyday workflows to be effective. Every member of the team needs a certain level of understanding regarding VDC in order to innovate and improve existing practices. Successful VDC implementation requires a thorough understanding of how things are done in theory as well as practice. Understanding the team's existing structure of decision making is crucial to implement effective new practices.

A VDC department's success depends not only on the talent of its team and strong process awareness, but also on clear organization. The structure of the VDC practice should evolve with each project, simplifying initial deployment, and incorporating lessons learned from previous projects, which are captured as a set of pre-formatted templates, databases, and a clearly organized file tree. Clear naming conventions and correctly implemented interoperability standards are the conduits that connect VDC to traditional AEC workflows and are addressed further in Chapter 5 ("Reference Documents").

## 2.1 VDC Services

VDC services broadly fall into three categories: implementation, production, and support services. Implementation includes consulting and educating a project team on the integration of VDC into a project's design-through-construction workflow. Writing up VDC Specifications and Implementation Plans, and maintaining the overall quality of models all fall into this category. Production is the work of creating deliverables and output from the various types of specialized information models outlined in section 2.2, each of which supports specific VDC services. Support services are those that include using the model to solve specific project issues that emerge throughout the course of the existing design and construction workflow. Examples of such services include litigation support and risk workshops.

### IMPLEMENTATION SERVICES

#### VDC Specifications

Specifications provide the rulebook for a project. They set expectations and outline how work should be performed. A good VDC Specification states what the information model should include and to what level of detail, as well as major information model deliverables for all phases of a project, from early design to the facility's final operations. The Specification should also reference the related global standard for level of model development. Global standards are in development for BIM and VDC. In the USA, the most prominent of these are the National BIM standards and the Level of Development document.[1] (For these standards, readers are referred to Chapter 5, "Reference Documents," which includes an example VDC Specification document.) Contracting bids are submitted based on the provided specifications.

How VDC should be integrated into a project greatly depends on how a team is organized. Every project has different requirements, and team organization varies based on the project's typology, size, complexity, client, location, phasing, and other requirements. A team's level of sophistication is an additional factor to consider. For example, where some parties are not sufficiently capable of operating information modeling software that might negatively affect how, or even if, VDC is incorporated into the process.

Providing detailed specifications that outline the implementation of a VDC process is extremely important. Any omission will likely adversely affect other aspects of the project; successful collaboration requires clearly defined standards. Essential standards for an information model include naming conventions, file structure, software workflows, component definitions, model completeness, and data output. Standardized formats for sharing 3-D data ensure the consistency and compatibility of both internal and external sharing.

Procedures for the implementation of new technology are essential, including the choice of software platform(s), identification of individuals who require software training, and analysis of existing technological infrastructure, including upgrades to targeted computers.

### VDC Implementation Planning

The VDC Specification should require the team member responsible for model authoring and model coordination to produce a VDC Implementation Plan. The plan is typically the responsibility of the design team during the design phase, the contractor during the construction phase, or the VDC consultant who is supervising coordination in either phase. A clearly defined Implementation Plan that answers all requirements in the specifications is essential for successfully integrating VDC. It not only outlines in detail how the VDC processes will be implemented and what software and hardware will be used, but also proves if the contractor has VDC capabilities. The Implementation Plan should include the contractor's project team structure as well as 3-D model standards with naming conventions, file organization, software workflows, component definitions, model completeness, and data output definitions. The Implementation Plan needs to be reviewed and approved by the CM, the design team and the owner's representative prior to commencing work. A sample Implementation Plan is included in Chapter 5.

### VDC Training

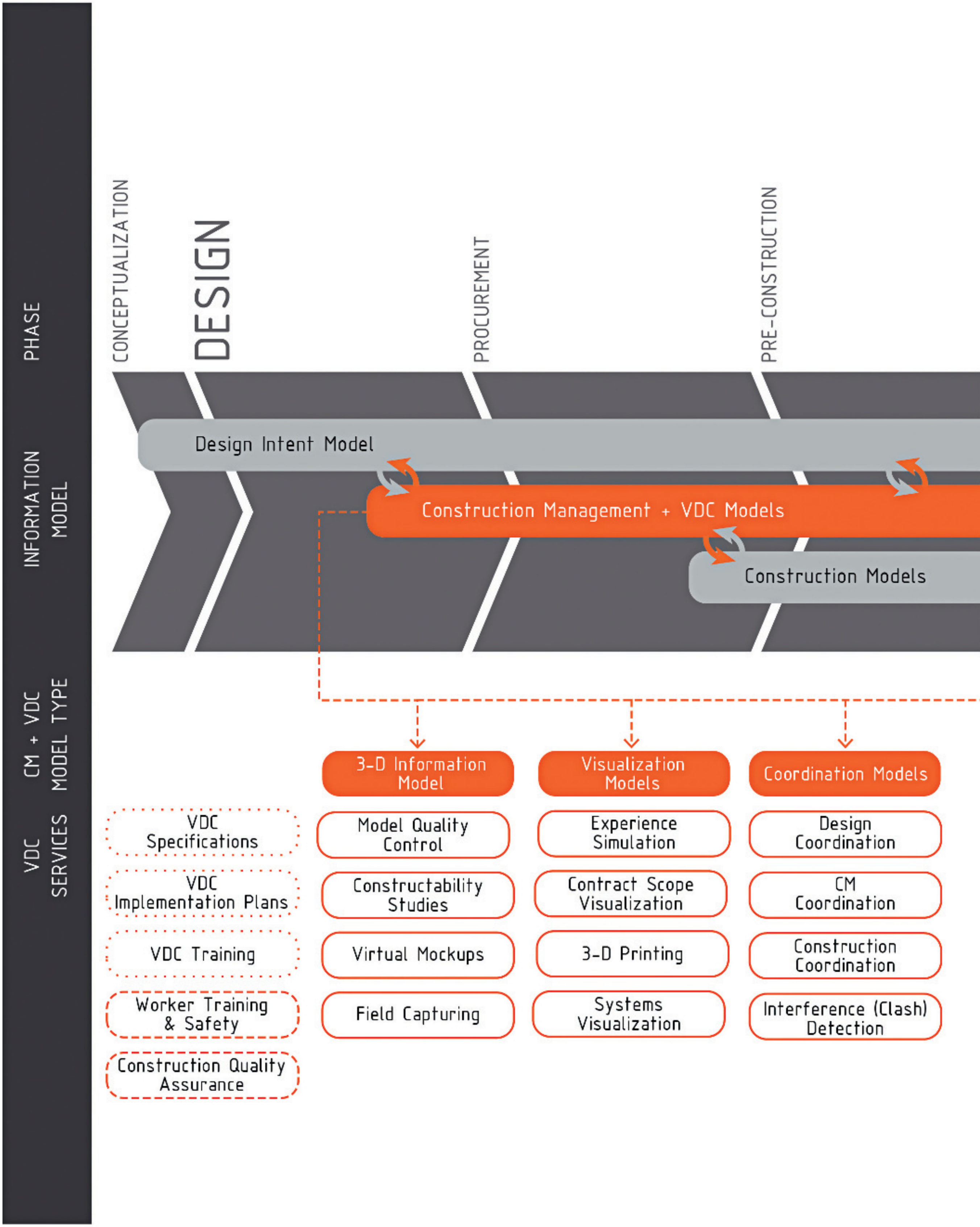
In order to ensure that the VDC workflows function well, all involved parties need to have sufficient knowledge in using VDC. At the inception of a project the skill set and required training need to be assessed. It is effective to have the party that is managing the VDC process to organize the training rather than outsourcing it.

## PRODUCTION SERVICES

**Figure 2.1.1** (overleaf)
Diagram of VDC models and services throughout typical AEC project phases

### Visualizations

Visualizing the model is sometimes a separate service, but often it is an integrated part of other VDC services, such as 4-D scheduling. Traditional visualization of project design through perspective drawings is almost as



PHASE
INFORMATION MODEL
CM + VDC MODEL TYPE
VDC SERVICES
CONCEPTUALIZATION
DESIGN
PROCUREMENT
PRE-CONSTRUCTION
Design Intent Model
Construction Management + VDC Models
Construction Models
3-D Information Model
Visualization Models
Coordination Models
VDC Specifications
VDC Implementation Plans
VDC Training
Worker Training & Safety
Construction Quality Assurance
Model Quality Control
Constructability Studies
Virtual Mockups
Field Capturing
Experience Simulation
Contract Scope Visualization
3-D Printing
Systems Visualization
Design Coordination
CM Coordination
Construction Coordination
Interference (Clash) Detection

# VDC PRACTICE DIAGRAM

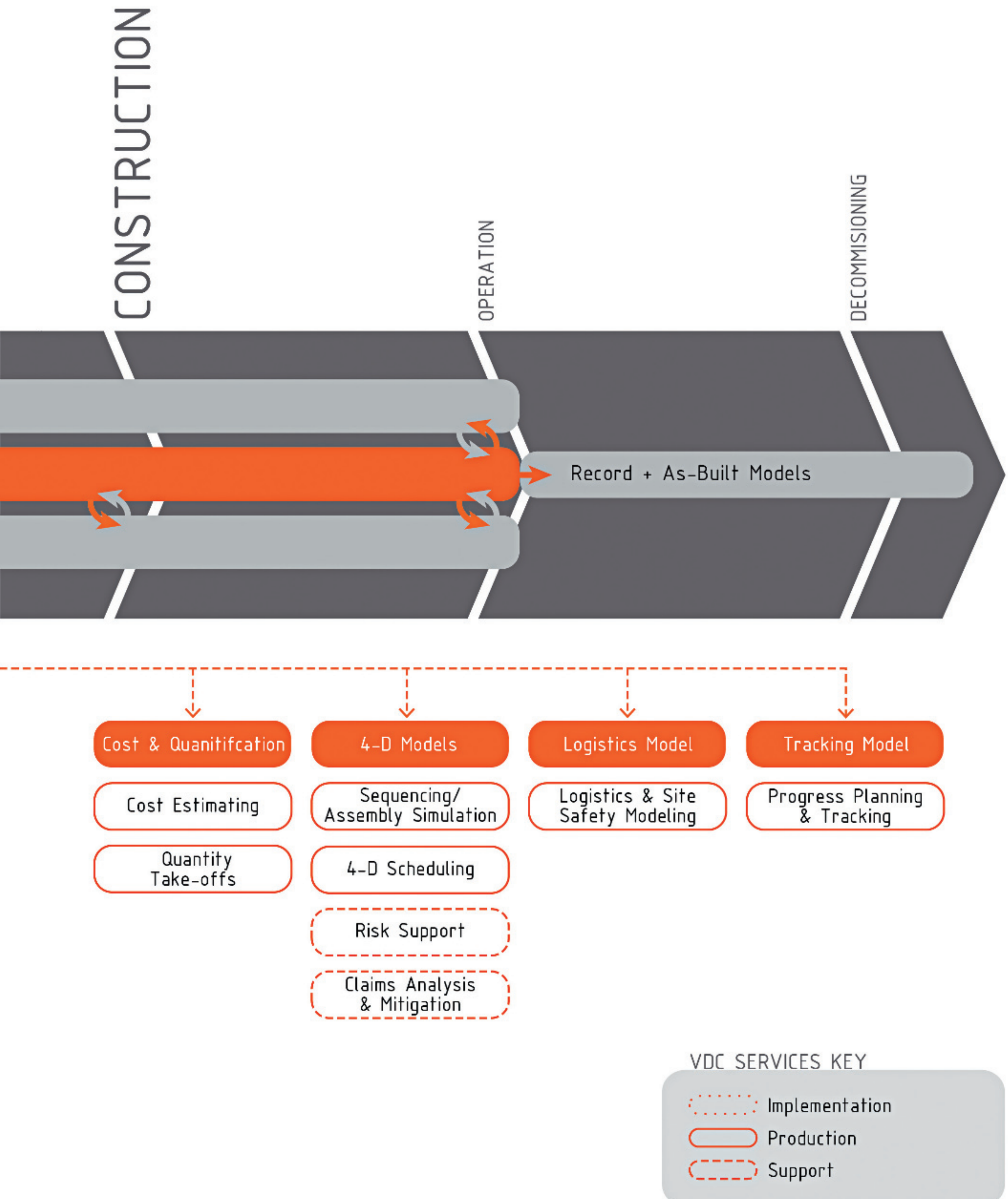



**Figure 2.1.2**
A still frame from a walk-through animation

old as the art of building itself. VDC tools make it possible not only to visualize specific views, but also generate performance-driven visualization and the construction of the building in sequence. Images, animations, live virtual walk-throughs, and experience simulations are gradually becoming standard project requirements. Visualization helps all parties quickly understand the project, especially participants who are not skilled in reading 2-D documentation and specifications. Identifying issues becomes crystal clear, and all parties can take part in the discussion to resolve them, rather than spend time and energy establishing the topic of discussion.

Depending on the need, it is possible to generate various types of visualization results, ranging from highly realistic experience animations that convey the final experience of the facility, to color-coded coordination studies meant to communicate concepts, discrepancies, performance criteria, issues, and interferences. Each type of visualization should be tailored to its specific audience.

### Experience Simulation

A walk-through of the final constructed design should be shown with the highest possible realism to convey as closely as possible the real experience of place.

### Systems Visualization

Visualizations used for systems coordination should be color-coded by subsystems, so some elements can be made transparent or turned off to bring relevant information to the forefront. A sophisticated VDC team tailors each visualization experience to include exactly the necessary data and highlight what is of interest. For some types of visualization it is best to provide both 2-D and 3-D representations, as 2-D helps with location information such as room, grid, zone, and levels.

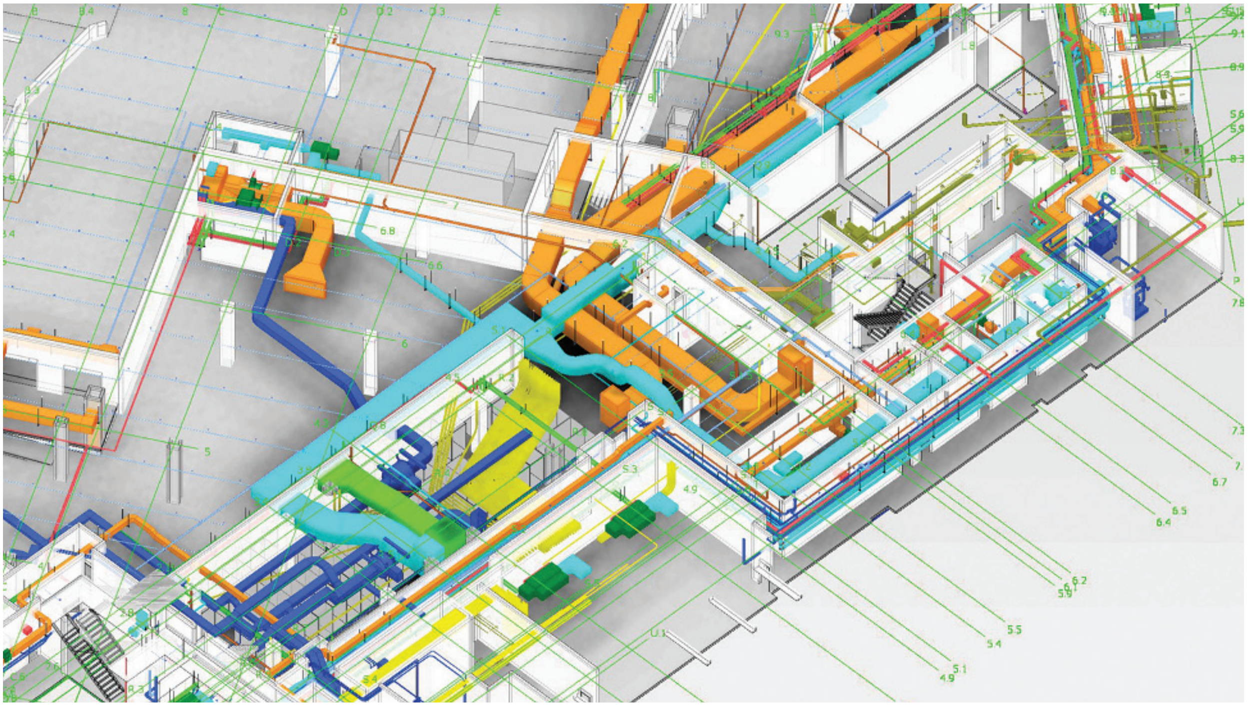


**Figure 2.1.3**
An example of systems visualization

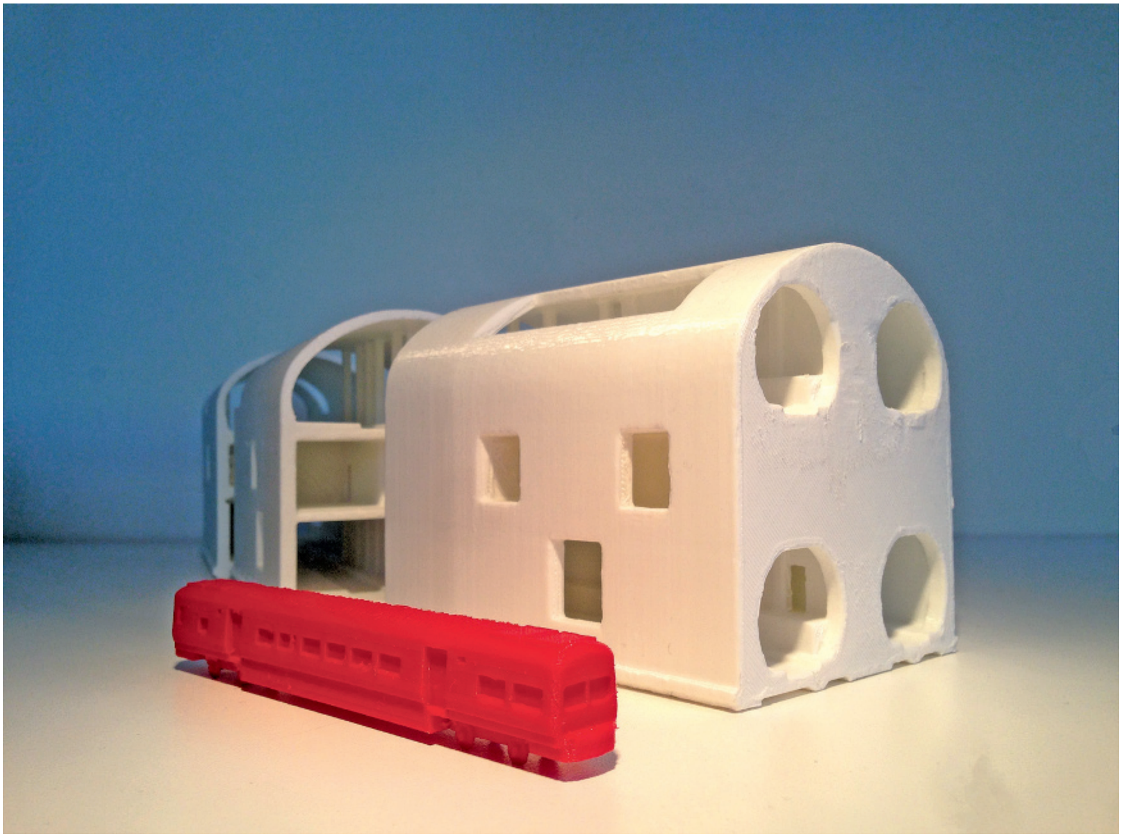


**Figure 2.1.4**
A 3-D printed prototype produced for an infrastructure project

### 3-D Prints

3-D printed models are useful for understanding construction sequencing as mockups; complex shapes or connections can be studied in detail. For project participants who are not fluent with computers, a 3-D print is easier to understand than a virtual model. 3-D printing technology is gradually becoming a tool for real manufacturing, such that large machines can produce real components of a building directly from the information model.

### Contract Scope Visualization

3-D modeling is a great platform for the contractor to quickly understand the scope of a project, particularly for projects that involve many contractors and subcontractors, with potentially complex interfaces and possible overlaps between different contract scopes. An information model can be used to clearly and precisely visualize the scope of different contractors' responsibilities, tie scope and costs to associated quantities extracted from a model, and highlight critical interfaces between contracts. This capability removes ambiguity and potential inconsistencies regarding different parties' responsibilities, and helps contractors to provide bids that correspond correctly to the proposed work.

### Proposal Presentations

Developers often issue Requests for Proposals (RFP) in order to select winning contracts for Design, Constructions Managers, and Contractor. Proposals include documents that illustrate their understanding of the project as well as proposed method of execution. This can include design, staging, phasing, access requirement, scheduling, team configuration, and a range of other qualifications. To help convey these concepts, VDC products can be included as an integrated part of any job proposal. This helps not only in communicating how the job would be run, but also demonstrates how VDC would be used throughout the project as an integrated part of everyday workflows.

### Field Capturing

With VDC, capturing existing spaces is usually done by laser scanning, creating an extremely accurate 3-D point cloud that includes every inch of visible surface area. This cloud can be linked to the information modeling authoring software and used to model the space or validate existing information models. Laser scanning is quickly becoming the preferred method of recording existing information, particularly as the equipment becomes faster and more cost-effective. Newer scanners use accurate colors in order to visualize a realistic environment. Information model authoring software is evolving such that architectural, structural, and systems components can now be modeled almost automatically, directly from the point cloud with the use of specialized software plugins.

Point clouds generated from laser scanning consist of millions of points, which results in gigantic amounts of data. A complete set of point clouds can exceed terabytes (TB) of data, so currently there is no practical way of distributing them over the internet. Often scanning consultants prefer to deliver point clouds using Blu-ray disks, as they hold up to 128 gigabytes (GB) of data that cannot be altered. It is important to keep in mind that saving files of that size can cause major issues with IT infrastructure because they take up so much drive space. Backup procedures might not be set up to handle such enormous amounts of data. Therefore projects that include modeling from a point cloud are often handled as separate tasks, with specific drives set up solely to handle point cloud data.

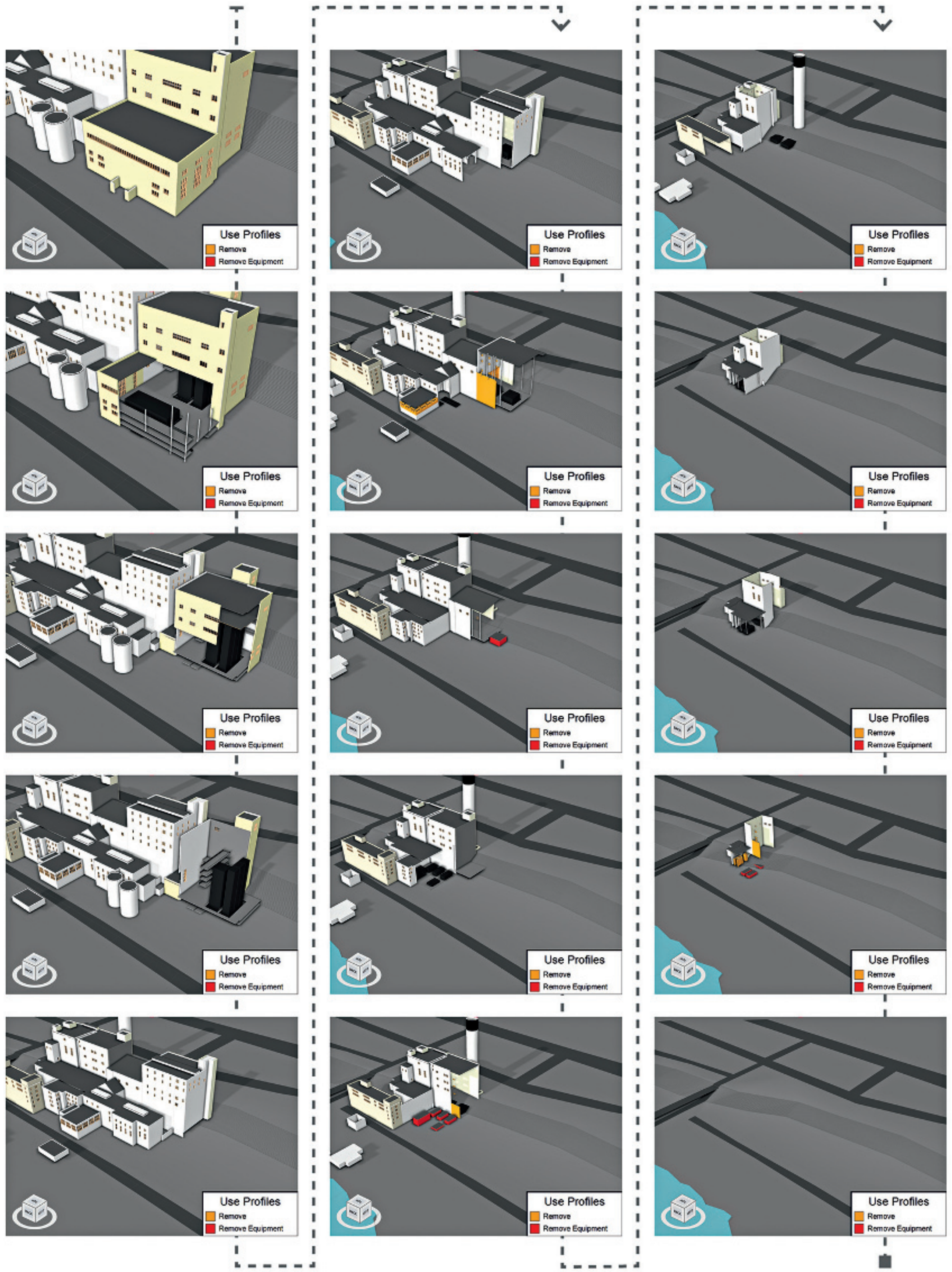



**Figure 2.1.5**
Proposal graphics: stills from an animation conveying the demolition of a power plant

**Figure 2.1.6**
A series of images exported from a point cloud of the Biltmore Room in Grand Central Station, New York City