Building Information Modeling (BIM)

for Construction Project Management

2013. 5.9.

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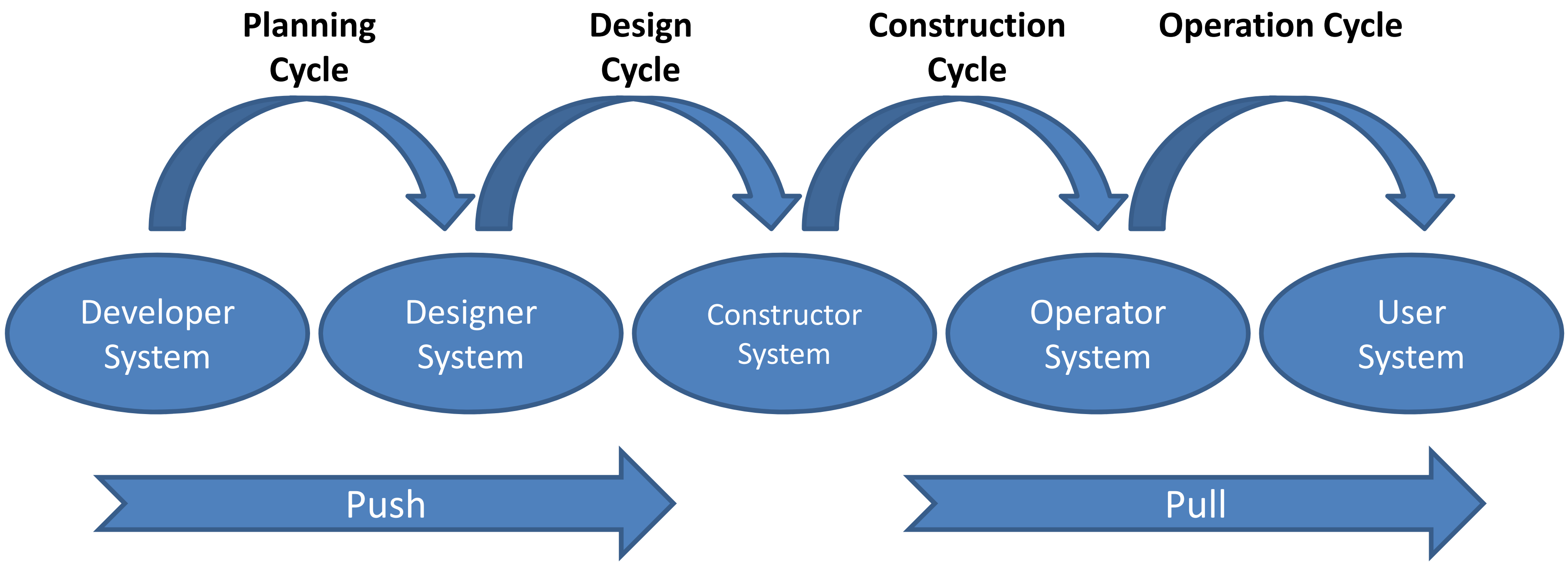
Needs

- “$15.8 billion is lost annually by the U.S. capital facilities industry resulting from inadequate interoperability due to the highly fragmented nature of the industry, the industry’s continued paper-based business practices, a lack of standardization, and inconsistent technology adoption among stakeholders“ – NIST (2004), "Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry"

Construction Supply Chain Review



Definitions

- An object-oriented building development tool that utilizes 5-D modeling concepts, information technology and software interoperability to design, construct and operate a building project, as well as communicate its details - Associated General Contractors
- The process of generating and managing building data during its life cycle – wikipedia
- A set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building's life-cycle – Succar (2009)

Industry Foundation Classes

- The Industry Foundation Classes (IFC) data model is a neutral and open specification that is not controlled by a single vendor or group of vendors.
- It is an object oriented file format with a data model developed by the International Alliance for Interoperability (IAI -> buildingSMART) to facilitate interoperability in the building industry, and is a commonly used format for Building Information Modeling (BIM).
- The IFC model specification is open and available.

(http://en.wikipedia.org/wiki/Industry_Foundation_Classes)

BIM software

- Autodesk – Revit, Inventor
- Beck Technology - DProfiler
- Bentley – Microstation
- Dassault – Catia, Delmia, Virtools
- Gehry Technologies – Digital Project
- Graphisoft – ArchiCAD
- Tekla – Tekla Structures

3D/4D CAD applicability areas in life cycle facility management

Phase	3D/4D CAD application area	Code
Planning	Early cost estimation	A1
	Construction site review	A2
	Conceptual project visualization	A3
Design	Parametric modeling to automatically update construction documents	B1
	Accurate design development	B2
	Quantity takeoff	B3
	Communication among different engineering fields	B4
	Communication among different contracting entities	B5
	Structural design support	B6
	Automatic design problem identification	B7
	Drawing documentation	B8
	Constructability analyses	B9
	Shop drawing replacement	B10
	Construction schedule estimation	B11

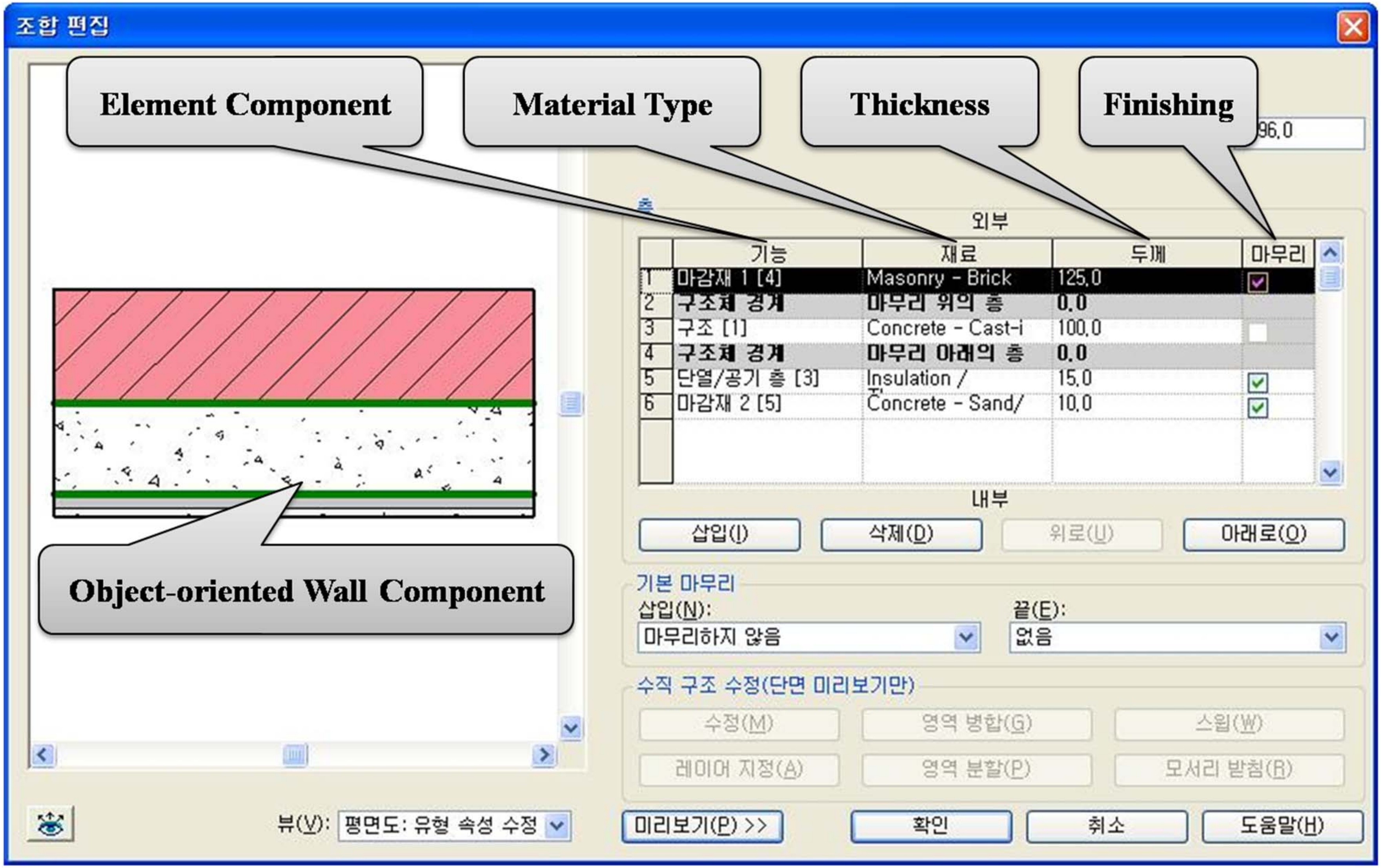
(Park et al. 2010)

3D/4D CAD applicability areas in life cycle facility management (Cont'd)

Phase	3D/4D CAD application area	Code
Construction	Shop drawing development	C1
	Collision check	C2
	Workspace analyses	C3
	Construction method review	C4
	Final product visualization	C5
	Quantity takeoff	C6
	Safety hazard prediction	C7
	Change order management	C8
	Time management	C9
	WBS development	C10
	Schedule evaluation	C11
	Comparison between as-planned and as-built models	C12
	Construction sequential logic testing	C13
	Digital mock-up testing	C14
Operation/ Maintenance	Rapid search for structural components	D1
	Shape identification of equipment components	D2
	Workspace analyses	D3
Life cycle	Communication across the facility life cycle	E1
	Communication among different engineering fields	E2
	Facility information formalization	E3
	Renovation facilitation	E4

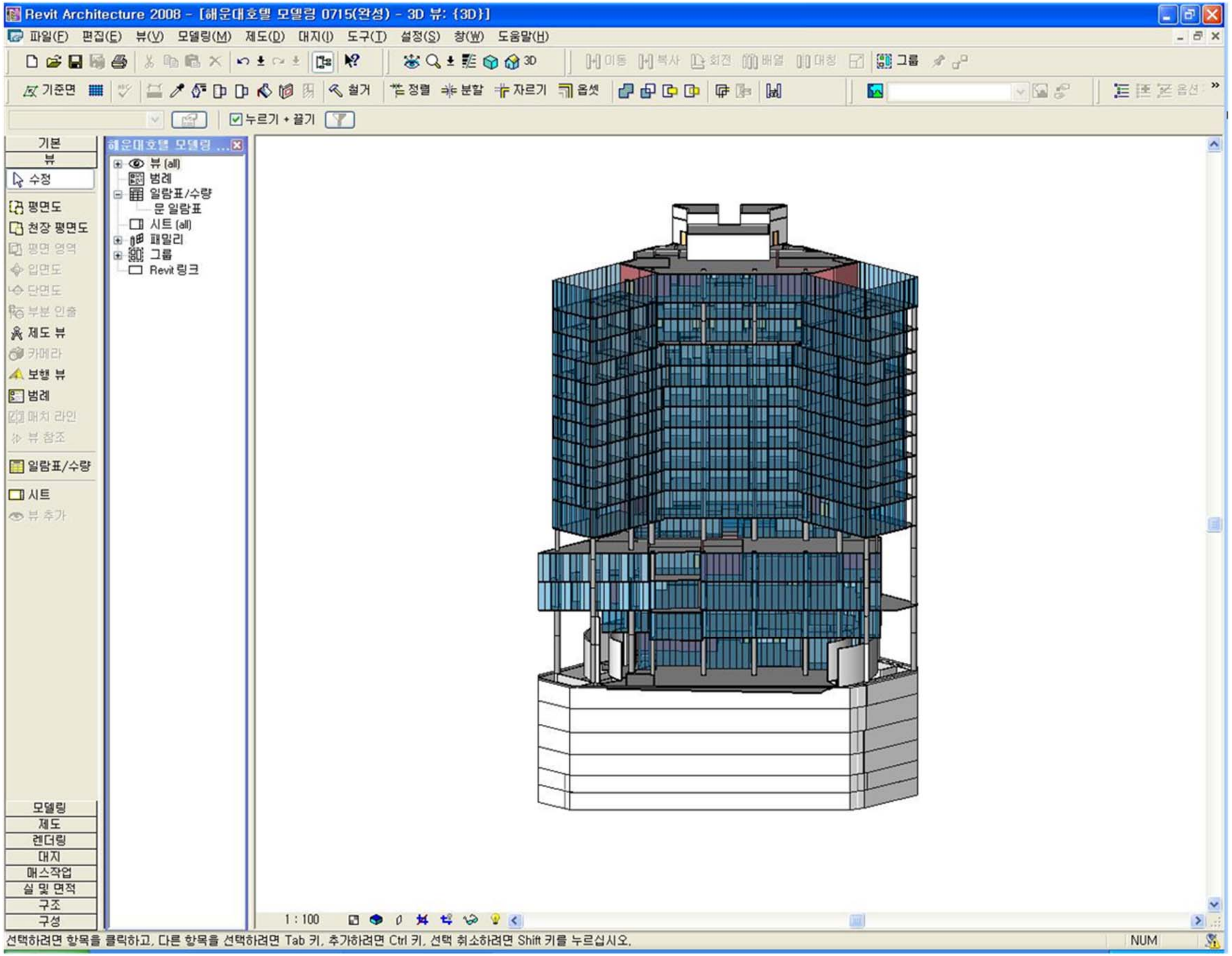
(Park et al. 2010)

3D component definition with parametric modeling and object-oriented concepts



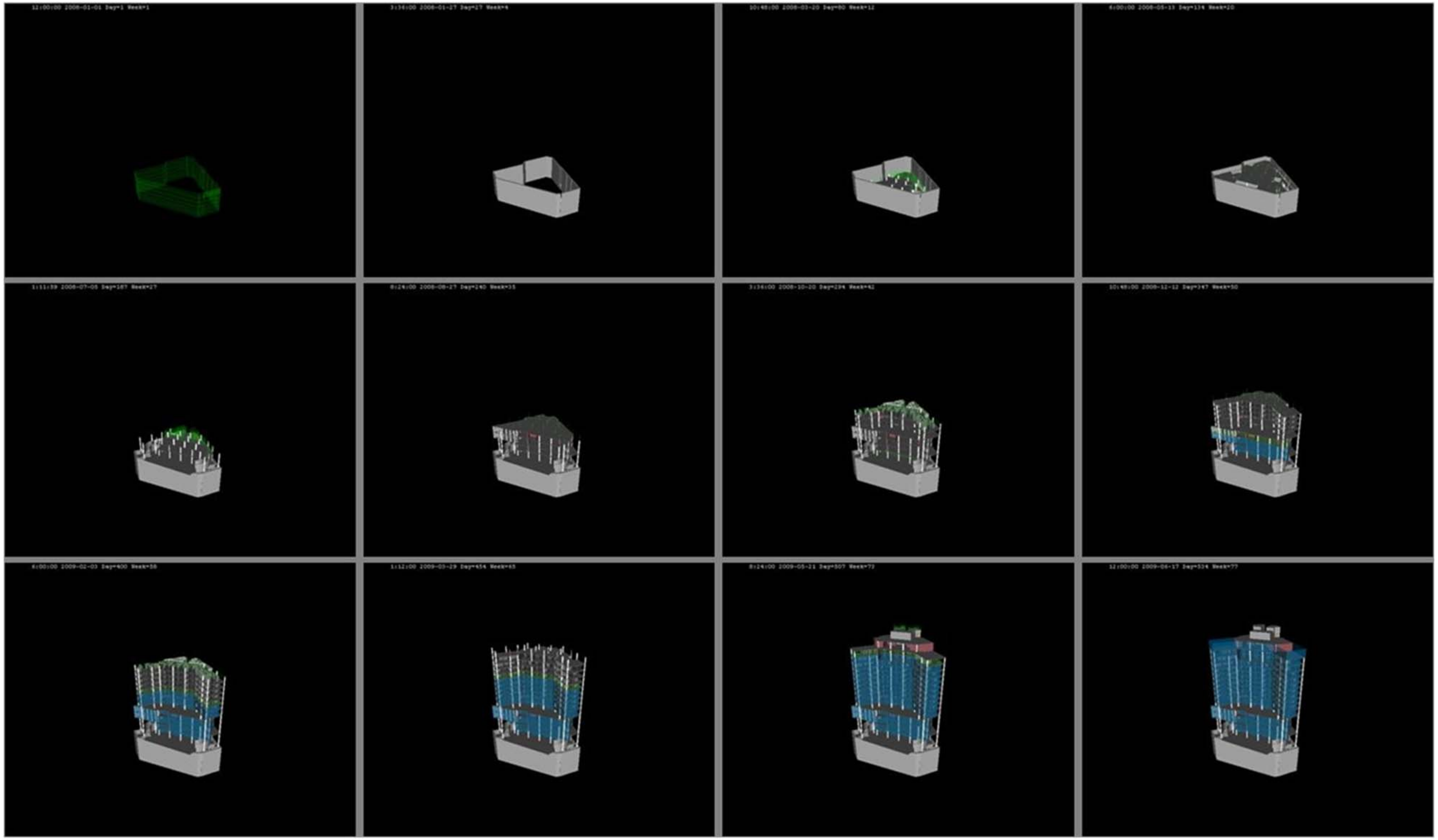
(Park et al. 2010)

3D CAD model for the Haeundae Hotel



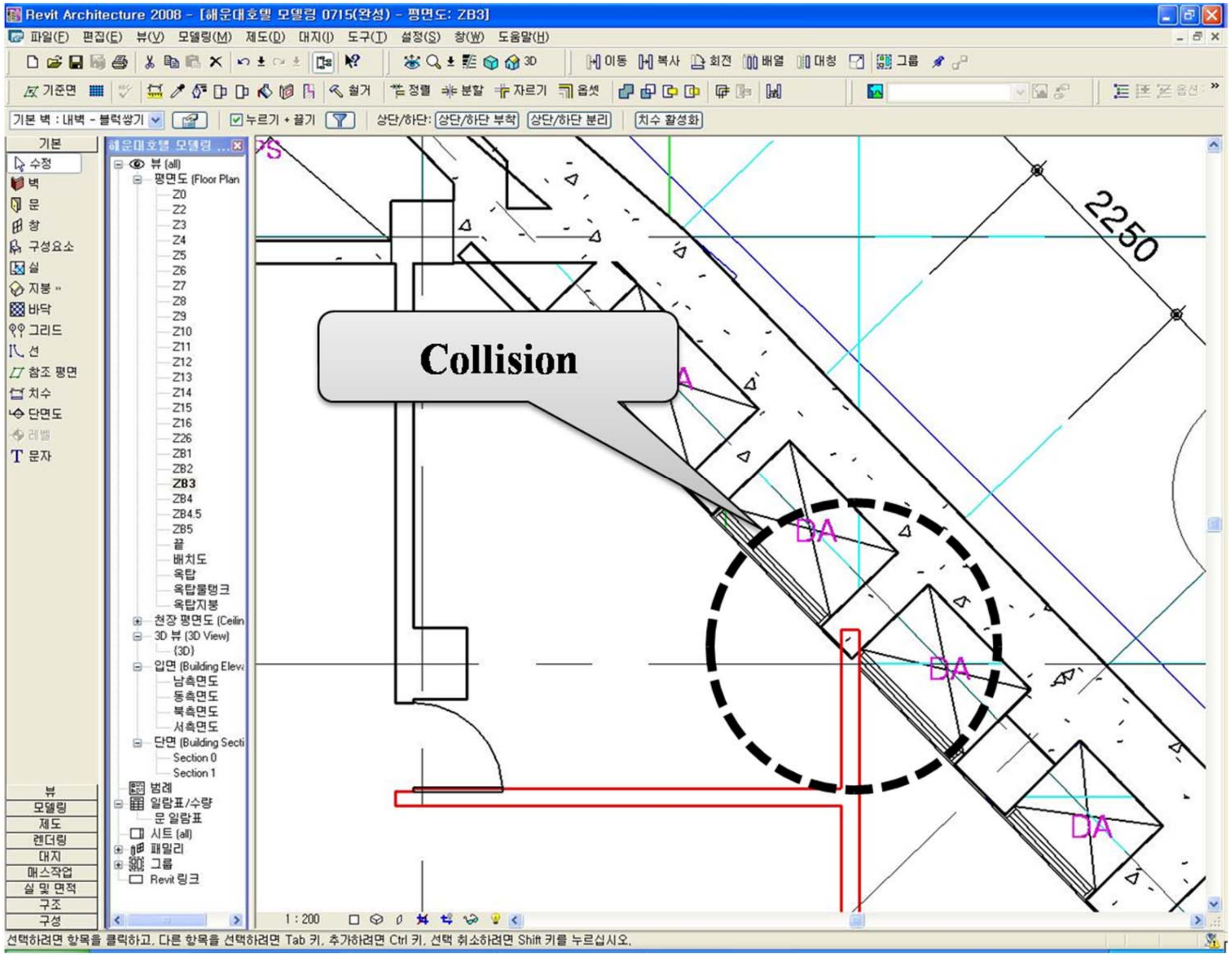
(Park et al. 2010)

4D CAD simulation for the Haeundae Hotel project



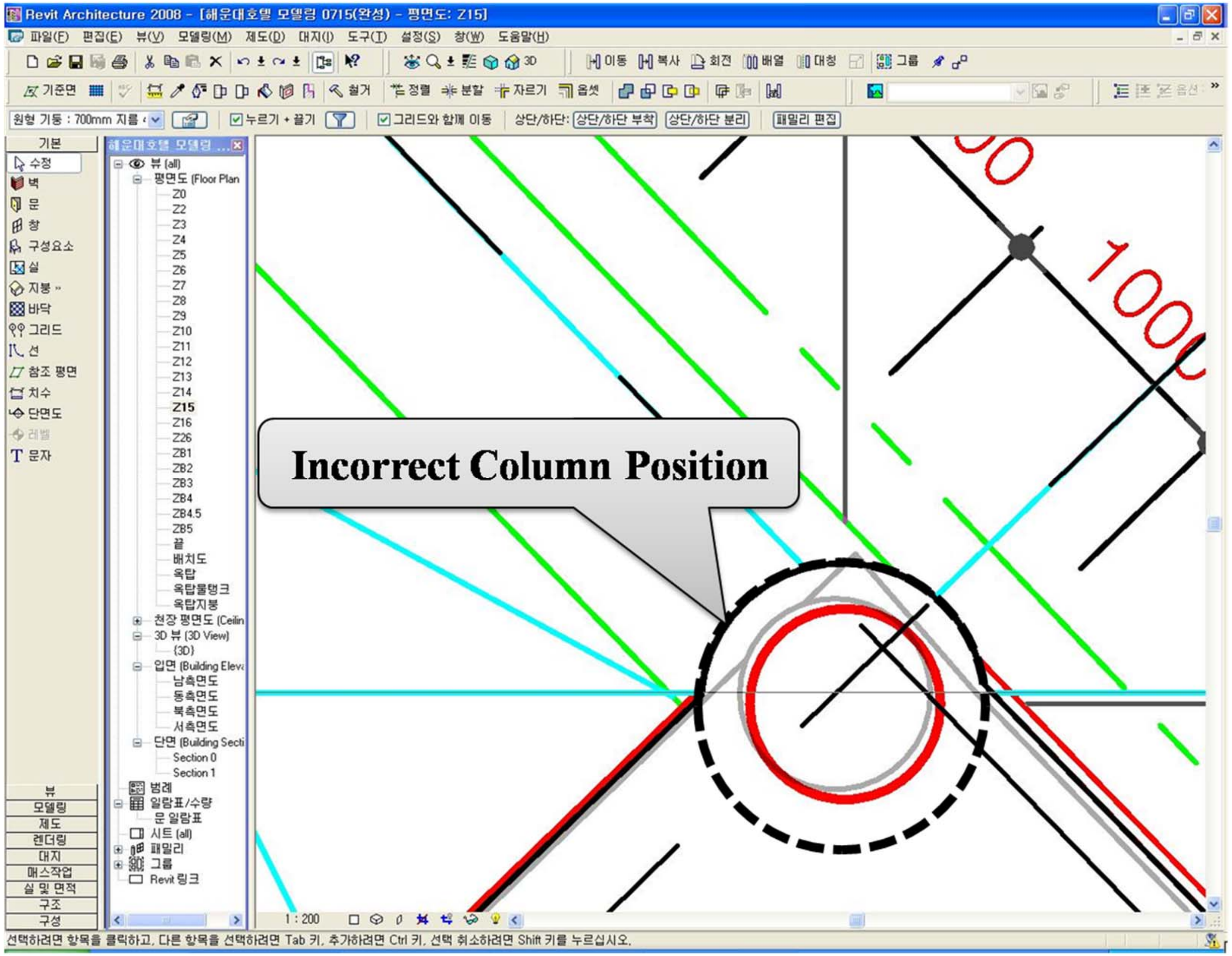
(Park et al. 2010)

Errors found by the 3D/4D CAD model: (a) wall collision



(Park et al. 2010)

Errors found by the 3D/4D CAD model: (b) incorrect column position



(Park et al. 2010)

Interactive 3D CAD for Effective Derrick Crane Operation in a Cable-Stayed Bridge Construction

- Cable stayed bridges have recently gained increasing popularity.
- The unique nature of a civil engineering project tends to require construction methods customized for the specific project.
- With this unique conditions in the one-of-a-kind construction site, the constructability is at stake.
- In this study, an interactive 3D CAD system is proposed to predict potential problems in cable-stayed bridge constructions.

(Park et al. 2009)

Two major methods for installing deck segments in cable-stayed bridge construction

Temporary bents method

Cantilever method

(Park et al. 2009)

Case study description

Cheongpoong Grand Bridge

- Project location
  - Chungcheongbukdo , Jaechon, Korea
- Specification of cable-stayed bridge
  - Total Length = 442m
  - Main Span Length = 327m
  - Height of Pylon = 103m

(Park et al. 2009)

Derrick crane for Cheongpoong Grand Bridge

(Park et al. 2009)

Derrick crane specifications

Item	Value
Boom length	19.65 m
Mast length	12.67 m
Total Height	17.64 m
Vertical speed	Up 0~1m/min; Down 0~1.5m/min
Turning speed	0.15 radian/min

(Park et al. 2009)

Deck segment installation procedure

1. As a precondition, the concrete deck of the side span is completed and two steel joints are connected to the concrete deck.
   - A rail is installed on the deck of the side span so as to easily move the derrick crane.
2. Move the derrick crane forward to the right position and anchor the crane to the lugs that are pre-installed.
3. Edge girders are moved and installed.
4. Man cages are placed for the bolting of the edge girders to the steel joints
5. Man cages are removed.
6. A safety net is installed using the two edge girders for the protection of the workers.
7. Floor beams are moved and installed.
8. Stringers are moved and installed.
9. Working platforms are moved and placed, and using the platforms, construction workers hang and partially stress cables

(Park et al. 2009)

Deck segment installation procedure (Cont'd)

10. The working platforms are removed.
11. Six precast concrete panels are, one by one, moved and installed.
12. Cast-in-place concrete are used to join the precast concrete panels with each other and to the steel structural members (edge girders, floor beams, and stringers), resulting in the formation of a deck segment.
13. After three days of concrete curing, the cables are partially stressed again for the adjustment to the newly formed deck segment.
14. The rail is extended.
    - The rail is composed of two pieces: front part and back part.
    - To extend the rail, the back part is detached from the deck and installed as the new front part
    - the original front part becomes the back part. In this way, the rail can move forward continually.
15. The steps from 2 to 14 are repeated until the finish of the deck construction.

(Park et al. 2009)

Derrick crane setting

(Park et al. 2009)

Edge girder installation

(Park et al. 2009)

Man cage

(Park et al. 2009)

Floor beam installation

(Park et al. 2009)

Stringer installation

(Park et al. 2009)

Working platform for cable hanging

(Park et al. 2009)

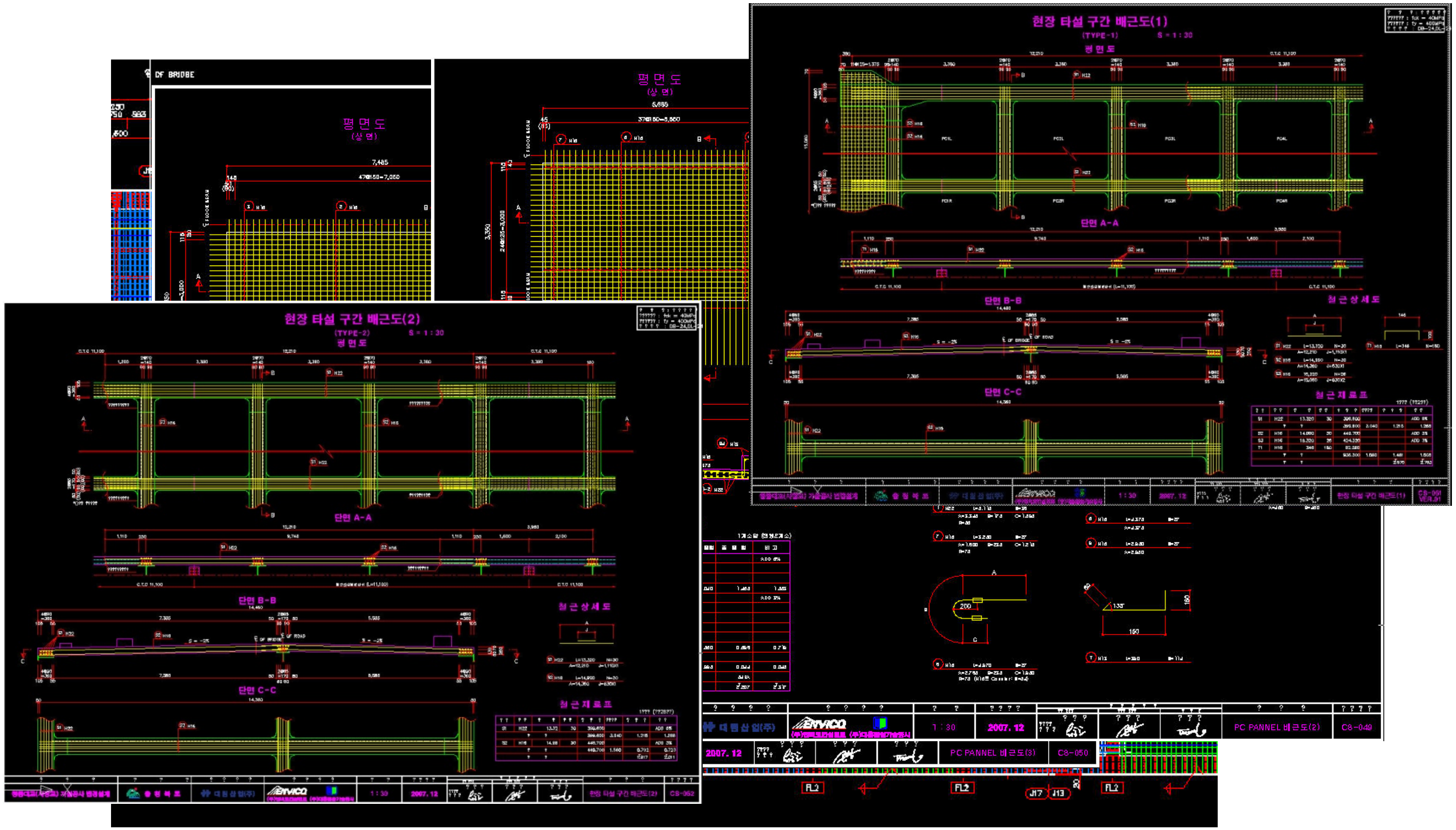
Precast concrete panel installation

(Park et al. 2009)

Cast-in-place concreting

(Park et al. 2009)

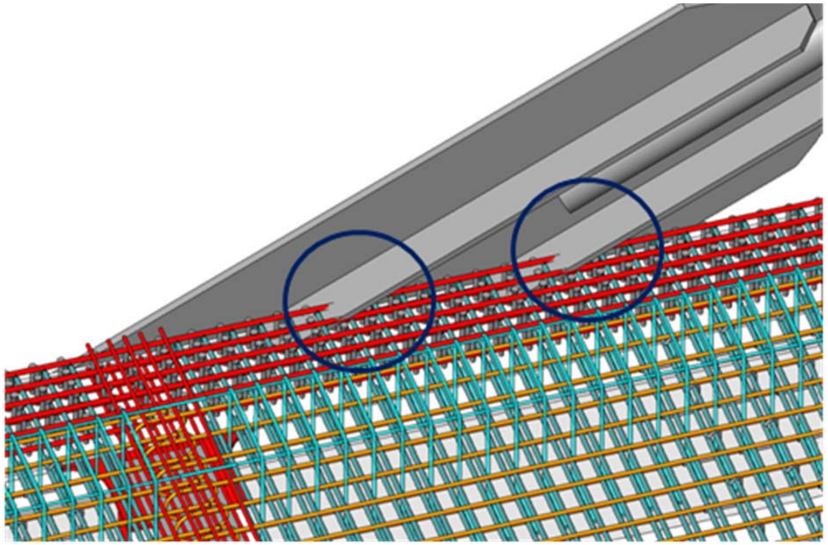
Collision Check of Structural Members



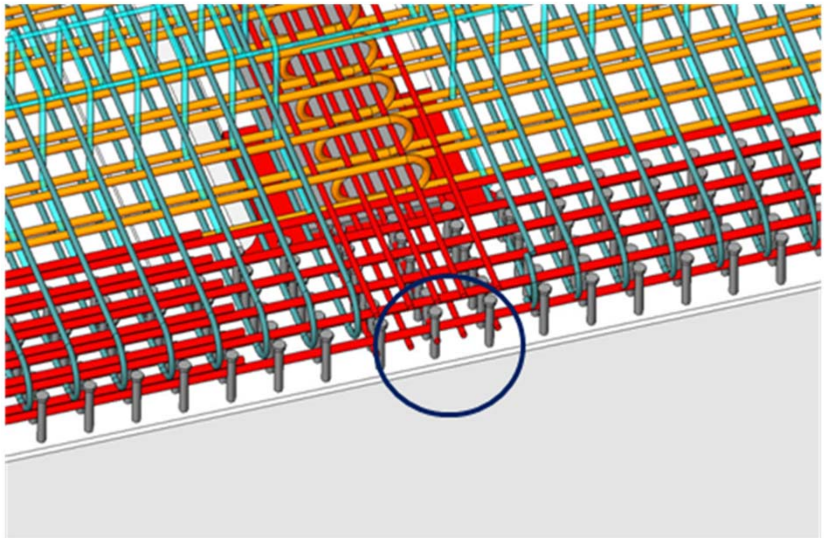
2D drawings

(Park et al. 2009)

Collision Check of Structural Members (Cont'd)



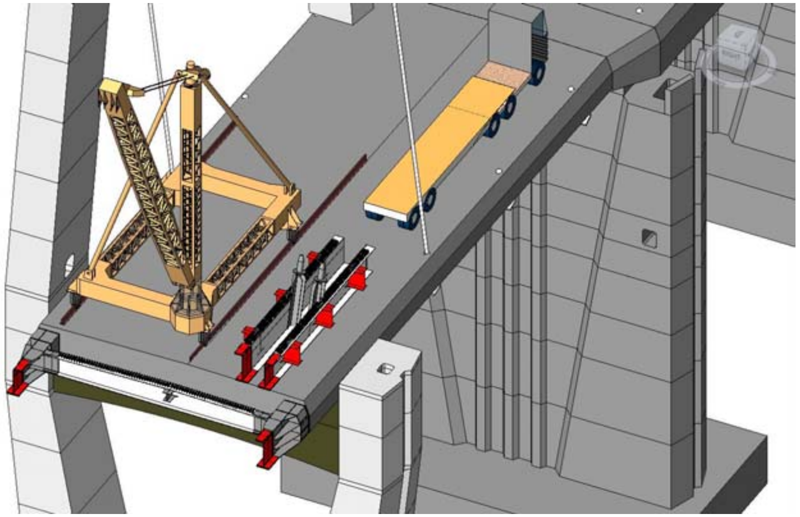
stay anchorage vs. reinforcing bar

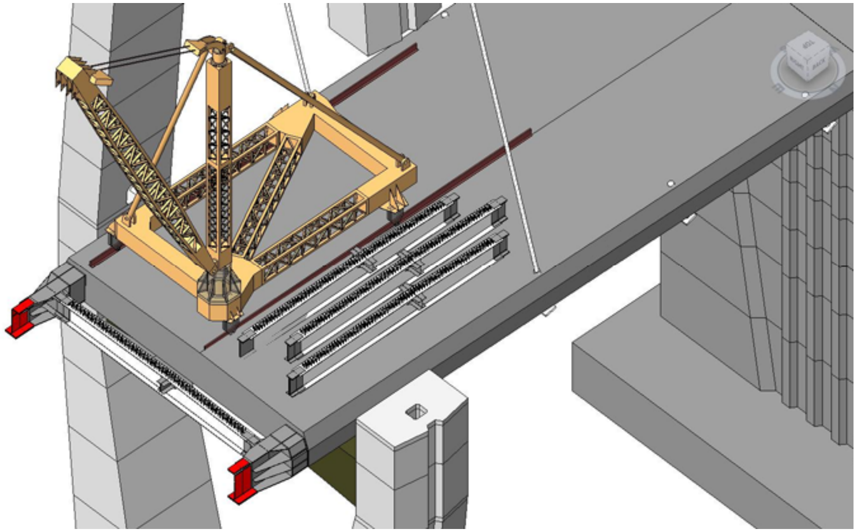


stud vs. reinforcing bar

(Park et al. 2009)

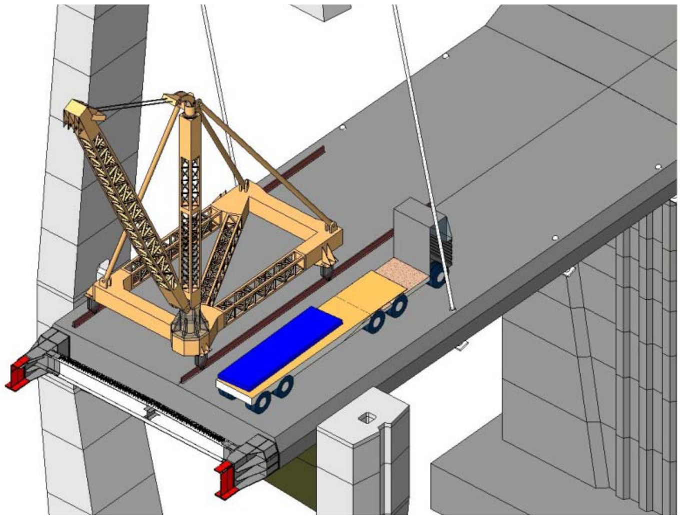
Material Unloading Space Analysis

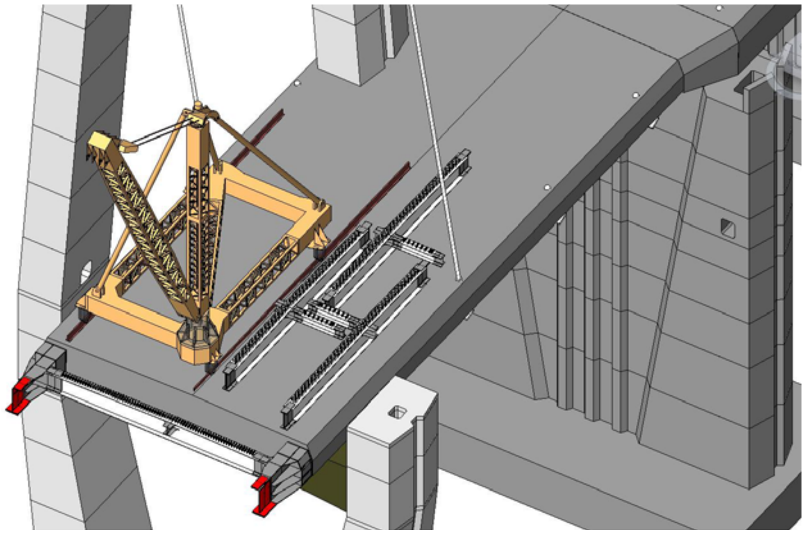




(Park et al. 2009)

Material Unloading Space Analysis (Cont'd)



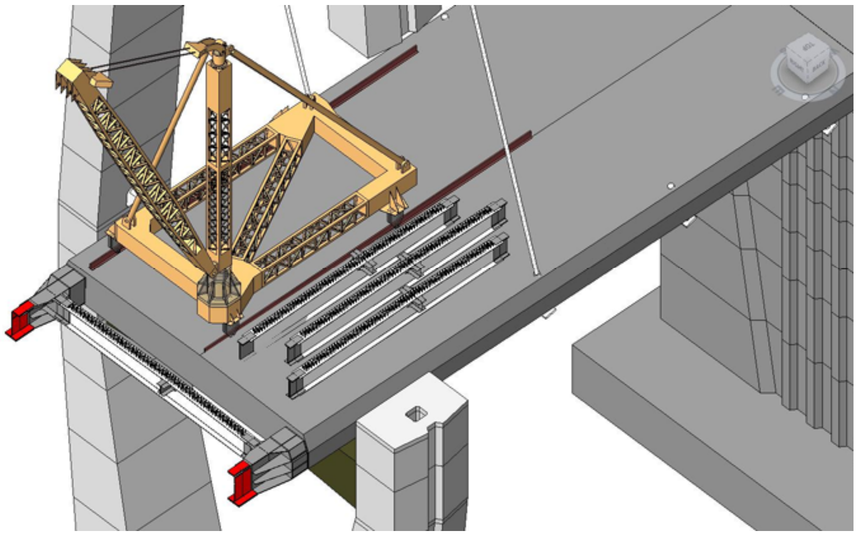


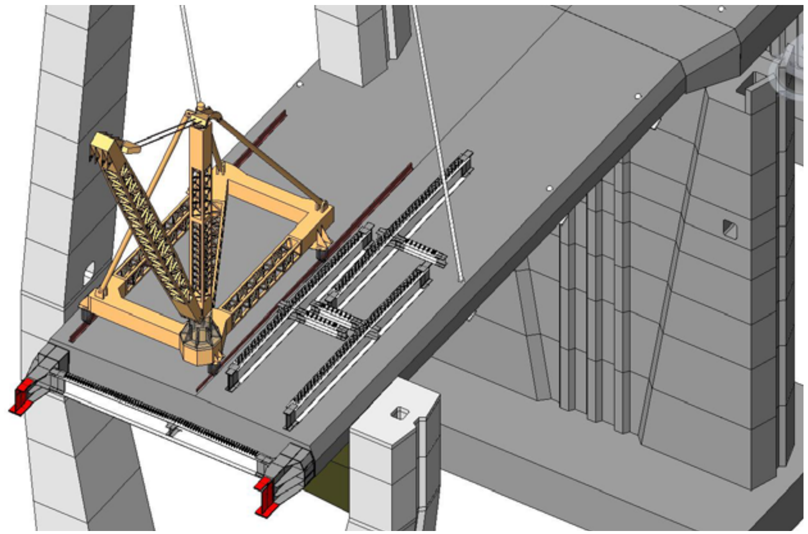
(Park et al. 2009)

Separate installation of floor beams and stringers

vs.

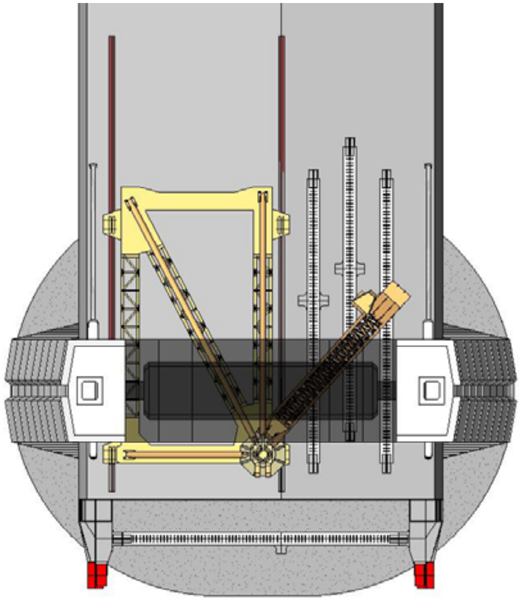
T-shape beams



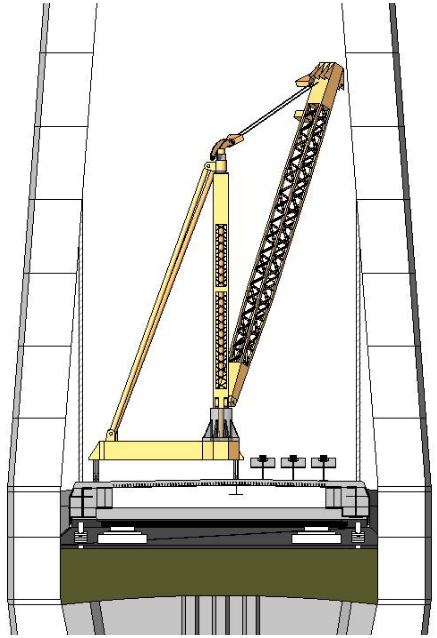


(Park et al. 2009)

Crane operation analyses



hoisting position



obstacle check in motion path

(Park et al. 2009)

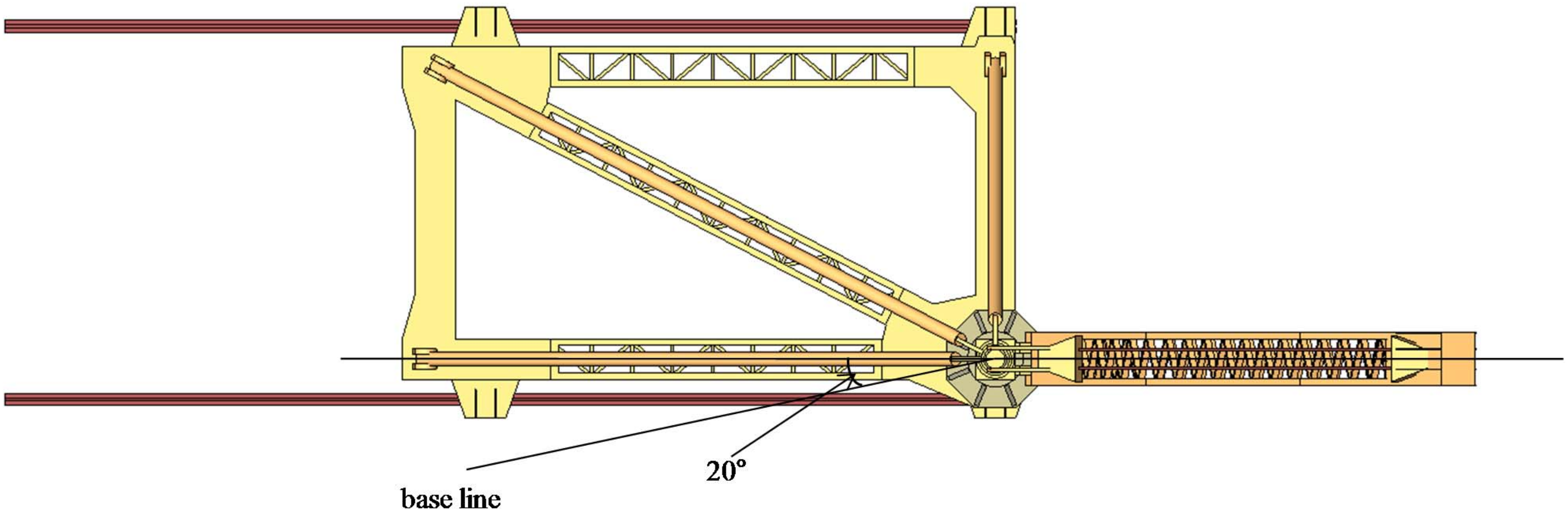
Crane operation analyses (Cont'd)

- Maximum capacity of the derrick crane for different structural components

Structural component	Weight	Maximum capacity of the derrick	
		Radius	Rotation angle (from the base line)
Edge girder	17 ton	13.53 m	245°
Floor beam	14.5 ton	16.1 m	245°
Stringer	8 ton	19 m	250°

(Park et al. 2009)

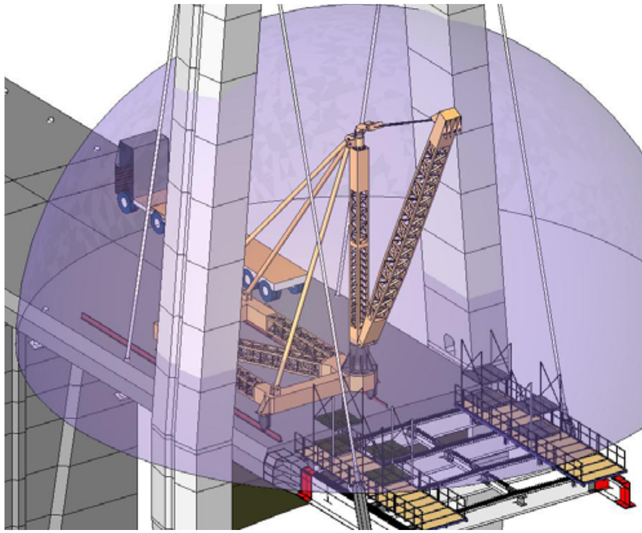
Crane operation analyses (Cont'd)



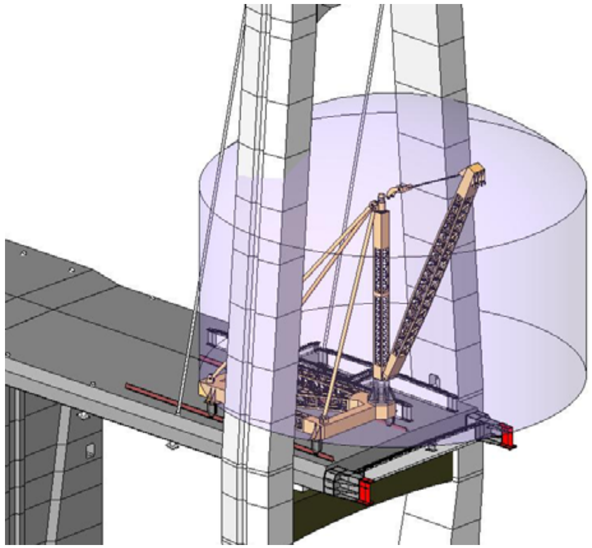
Baseline of the boom rotation

(Park et al. 2009)

Crane operation envelopes with different loading conditions



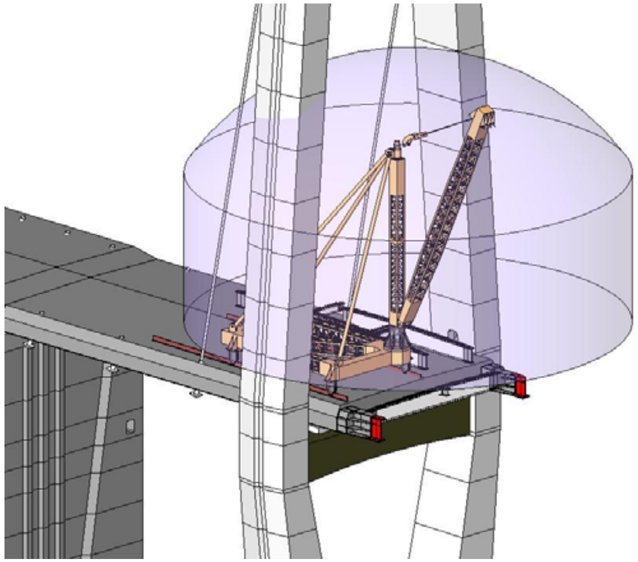
no load



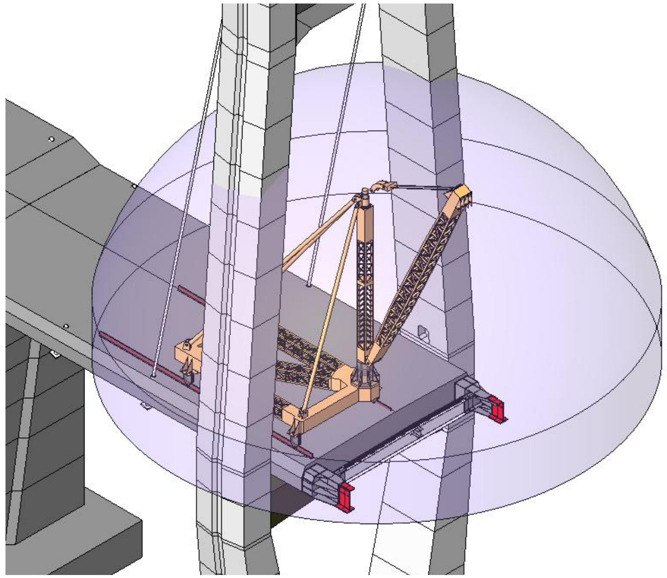
edge girder

(Park et al. 2009)

Crane operation envelopes with different loading conditions (Cont'd)



floor beam



stringer

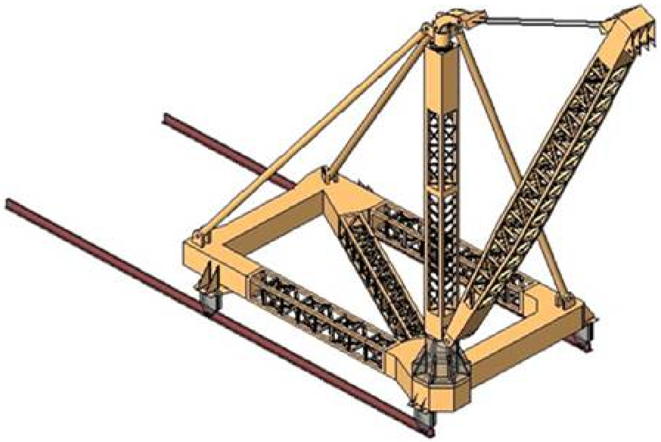
(Park et al. 2009)

Applicability of 4D CAD in Civil Engineering Construction

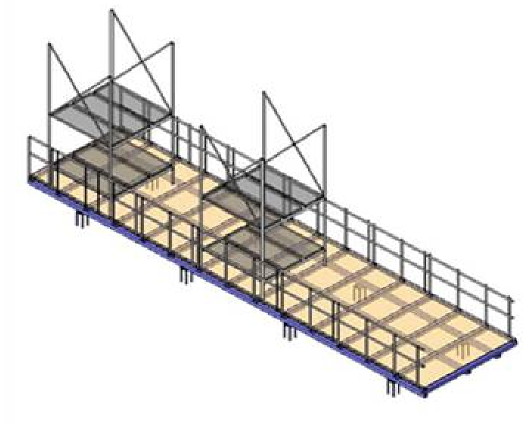
- Unsatisfactory performance of construction projects often originates from inappropriate design, incomplete construction planning, and/or lack of communication between construction practitioners.
- To overcome the inefficiency of construction project management, constructability-oriented planning at the pre-construction or construction phase is essential.
- Four dimensional (4D) computer-aided design (CAD) is one of the promising methodologies that has been studied to aid in construction planning.
- However, there is a lack of 4D CAD application in the area of civil engineering

(Kim et al. 2011)

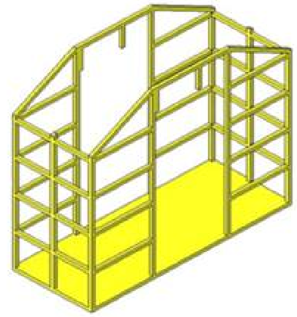
3D modeling of structural components for 4D visualization



(a) Derrick Crane



(b) Working Platform



(c) Men Cage

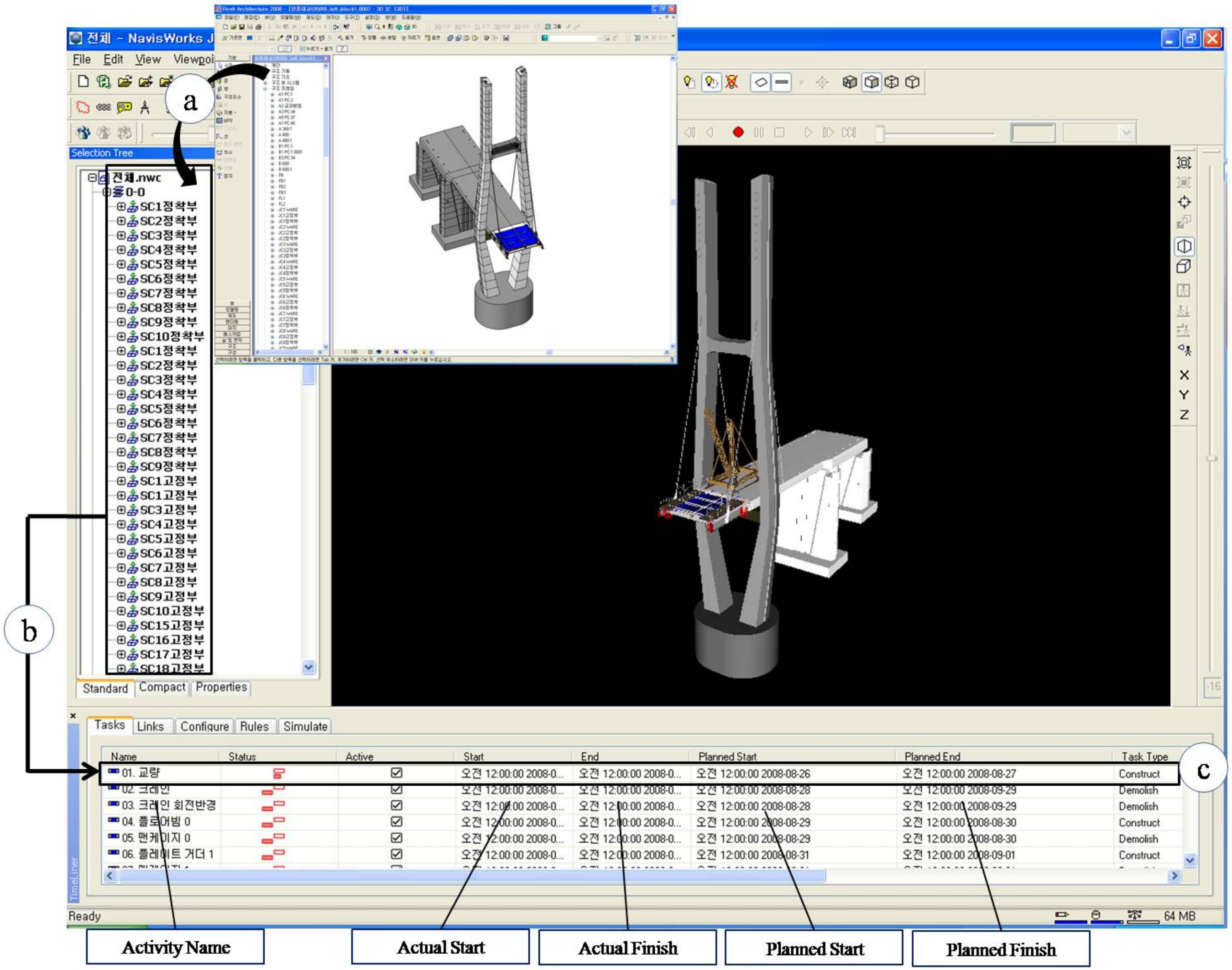
(Kim et al. 2011)

4D CAD modeling on the activity level

- To develop a 4D model, time schedule information is integrated with the existing 3D CAD components.
- Generally, 3D CAD systems that are currently available in the market do not have built-in functions that allow for this kind of information integration.
- In this study, commercial software – JetStream produced by NavisWorks – was used to combine the 3D CAD and time information.

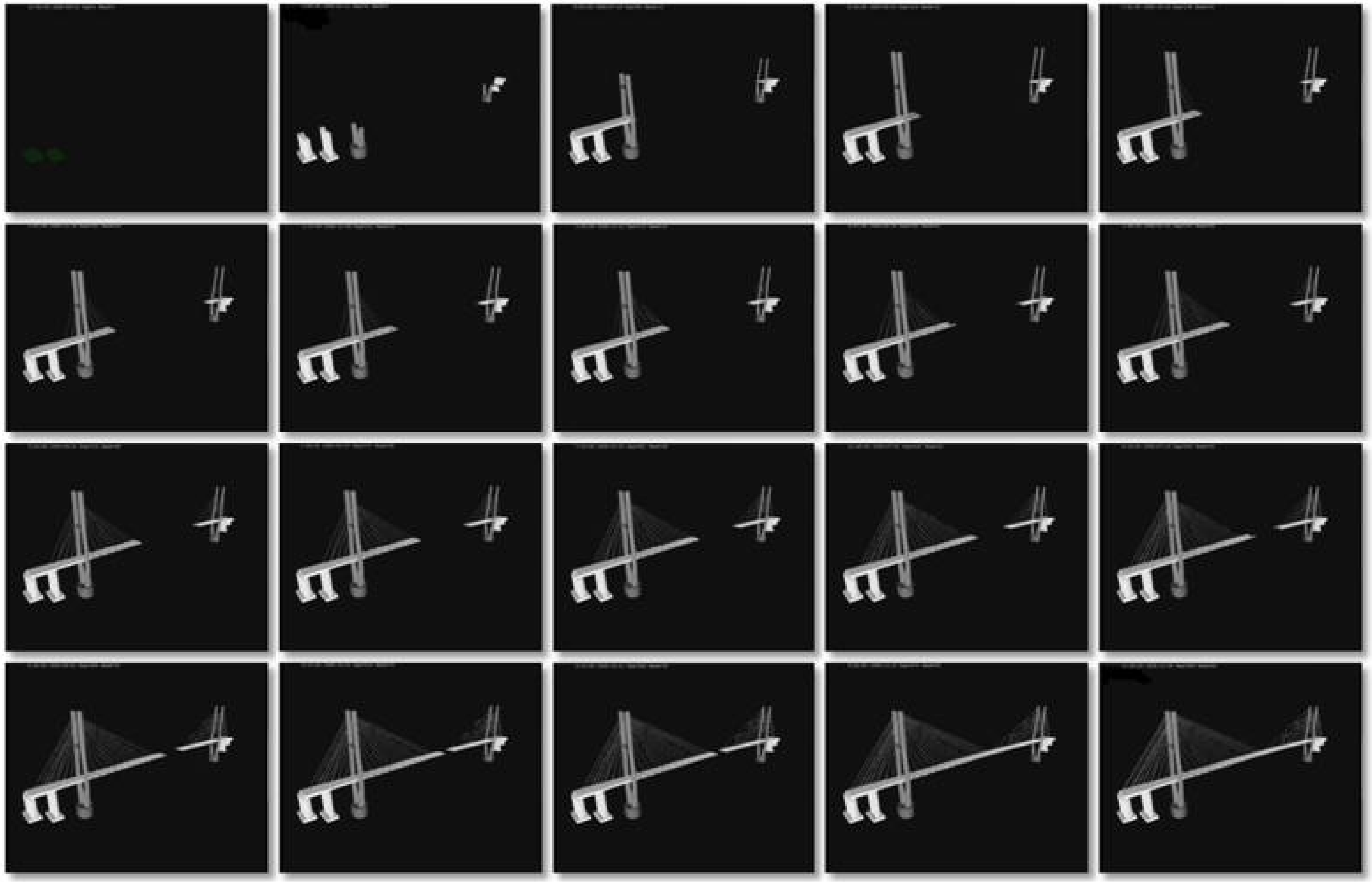
(Kim et al. 2011)

4D CAD modeling on the activity level (Cont'd)



(Kim et al. 2011)

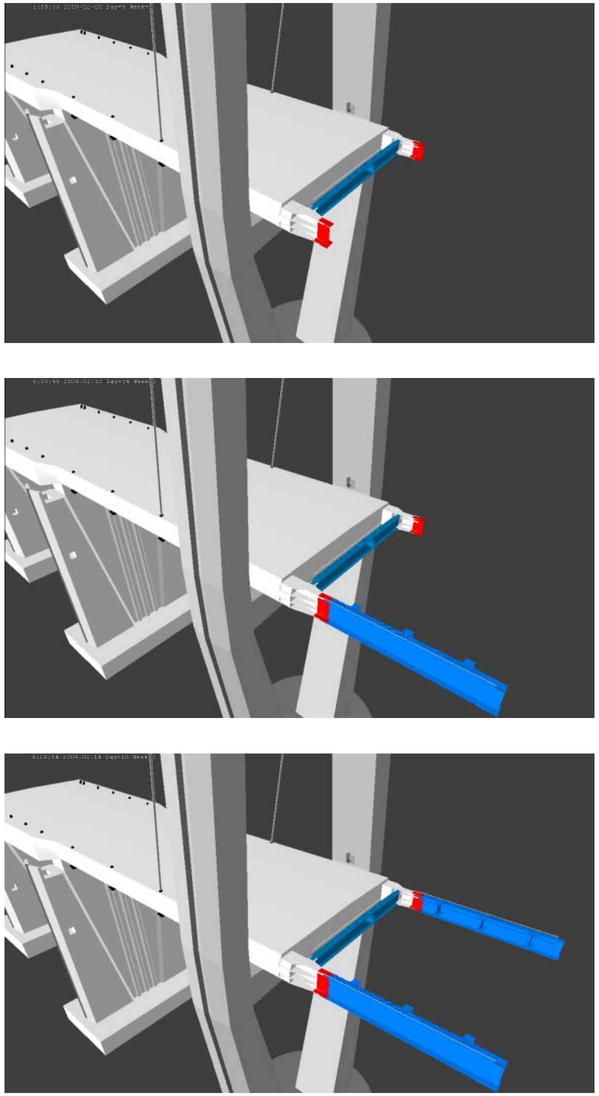
4D CAD modeling on the activity level (Cont'd)



(Kim et al. 2011)

Comparison between activity and operation level 4D CAD

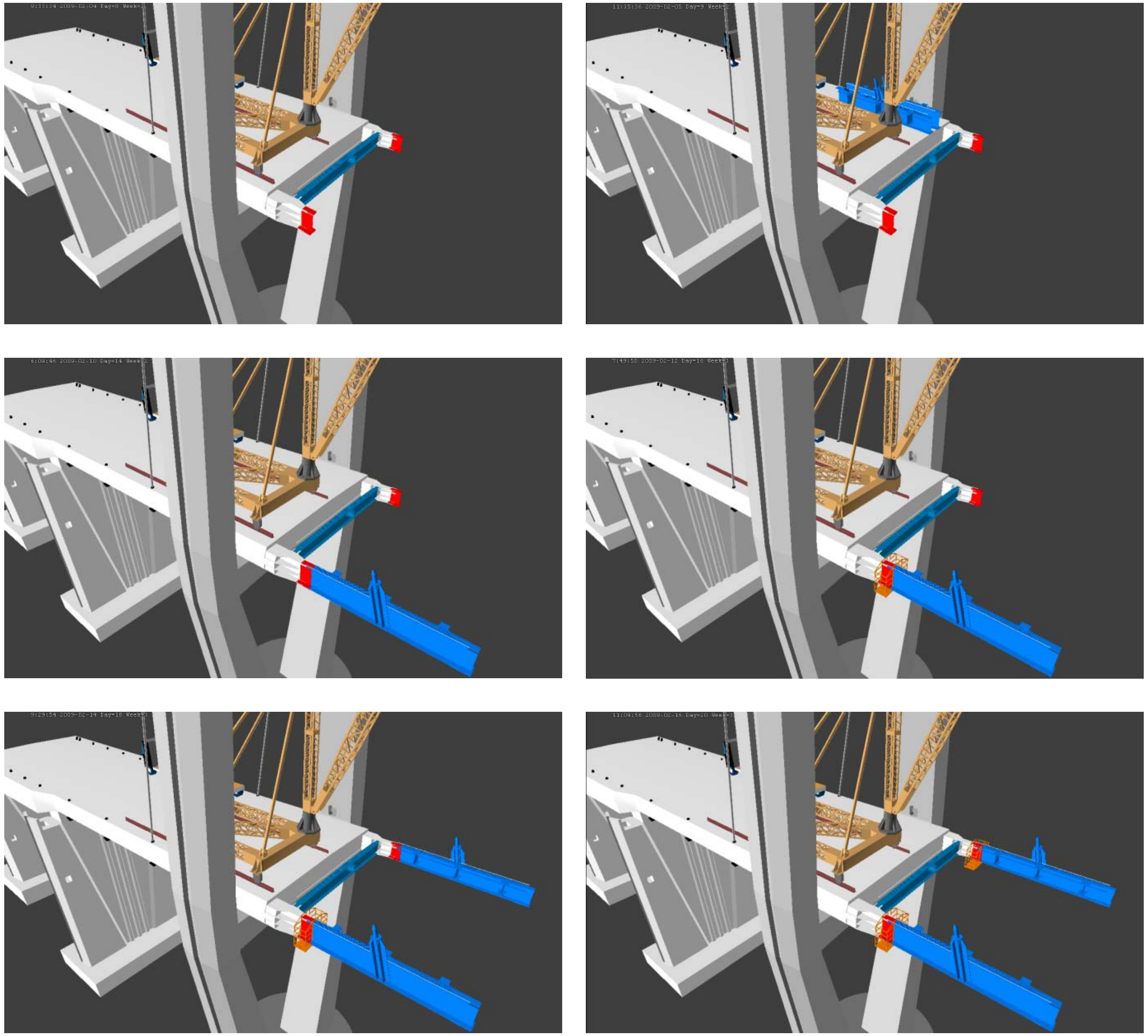
Activity level 4D CAD



(Kim et al. 2011)

Comparison between activity and operation level 4D CAD (Cont'd)

Operation level 4D CAD



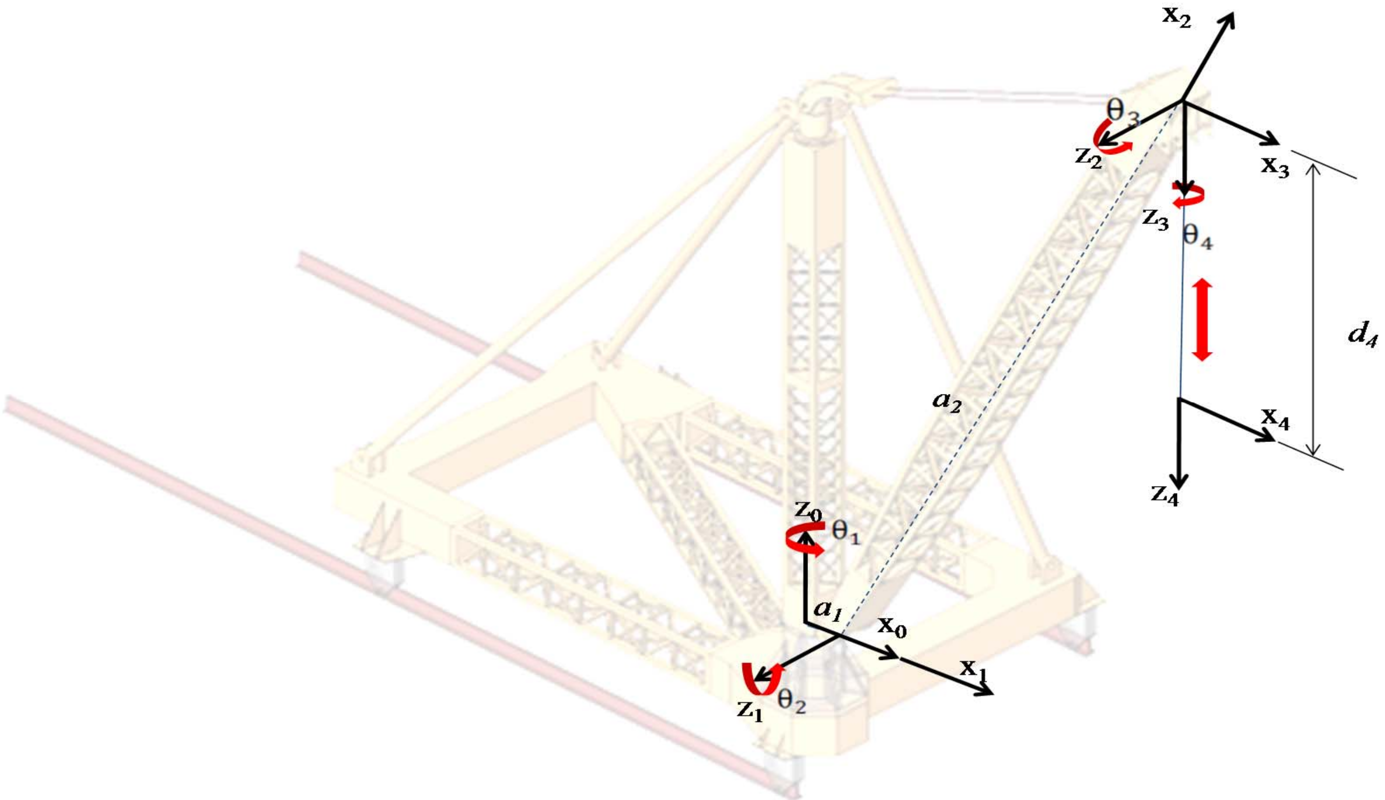
(Kim et al. 2011)

Continuous 4D CAD modeling on the operation level

- ‘Continuous’ 4D CAD modeling signifies that the resultant model depicts the construction operation for a continuous period of time, with no time lapses.
- In this methodology, entire movement processes of construction equipment, such as derrick cranes and trailers, are displayed like motion pictures.
- In this study, the continuous 4D CAD model was developed in the Autodesk Inventor platform.

(Kim et al. 2011)

Continuous 4D CAD modeling on the operation level (Cont'd)

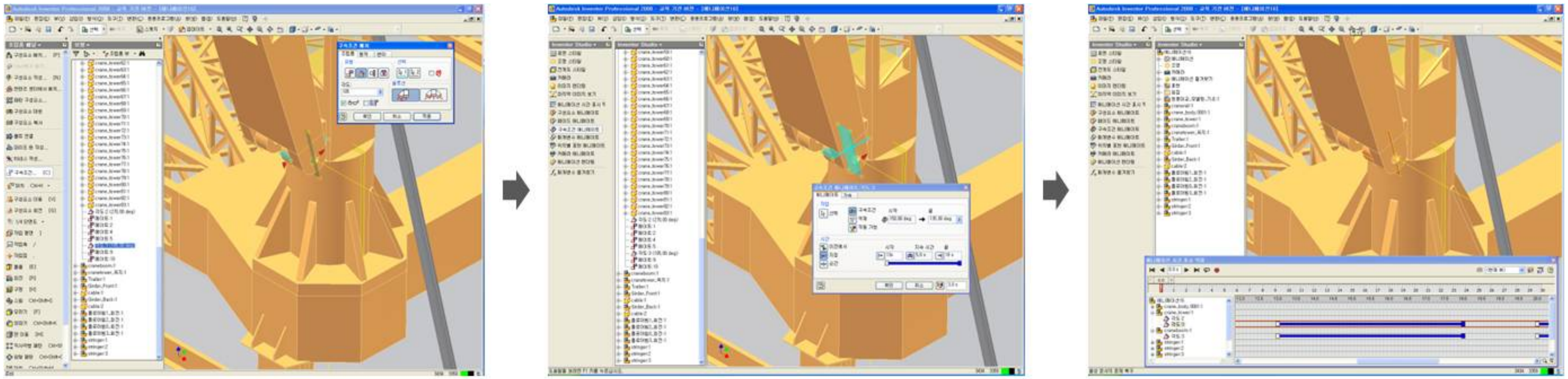


Reference frames for the derrick crane operation

(Kim et al. 2011)

Continuous 4D CAD modeling on the operation level (Cont'd)

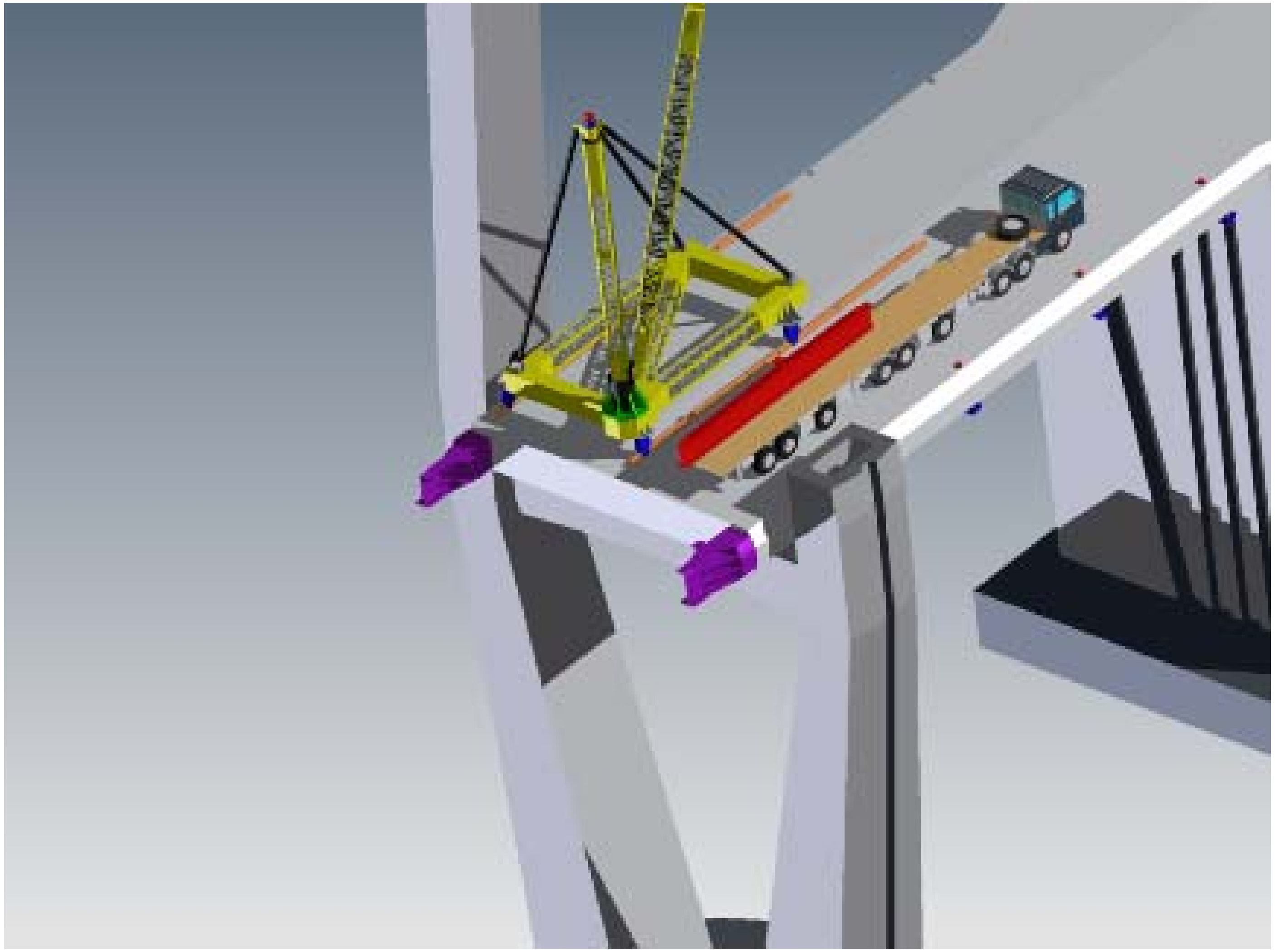
- In the Inventor platform, the local coordinate systems are defined based on the concept of constraint conditions.
- Constraint conditions are established to define the object to be moved and the reference frame.
- The following figures shows the overall process of developing a continuous operation level 4D CAD model with three steps: definition of constraint conditions, range setup for movement angles and distance, determination of movement durations with start and end times.



(a) (b) (c)

(Kim et al. 2011)

Continuous 4D CAD modeling on the operation level (Cont'd)



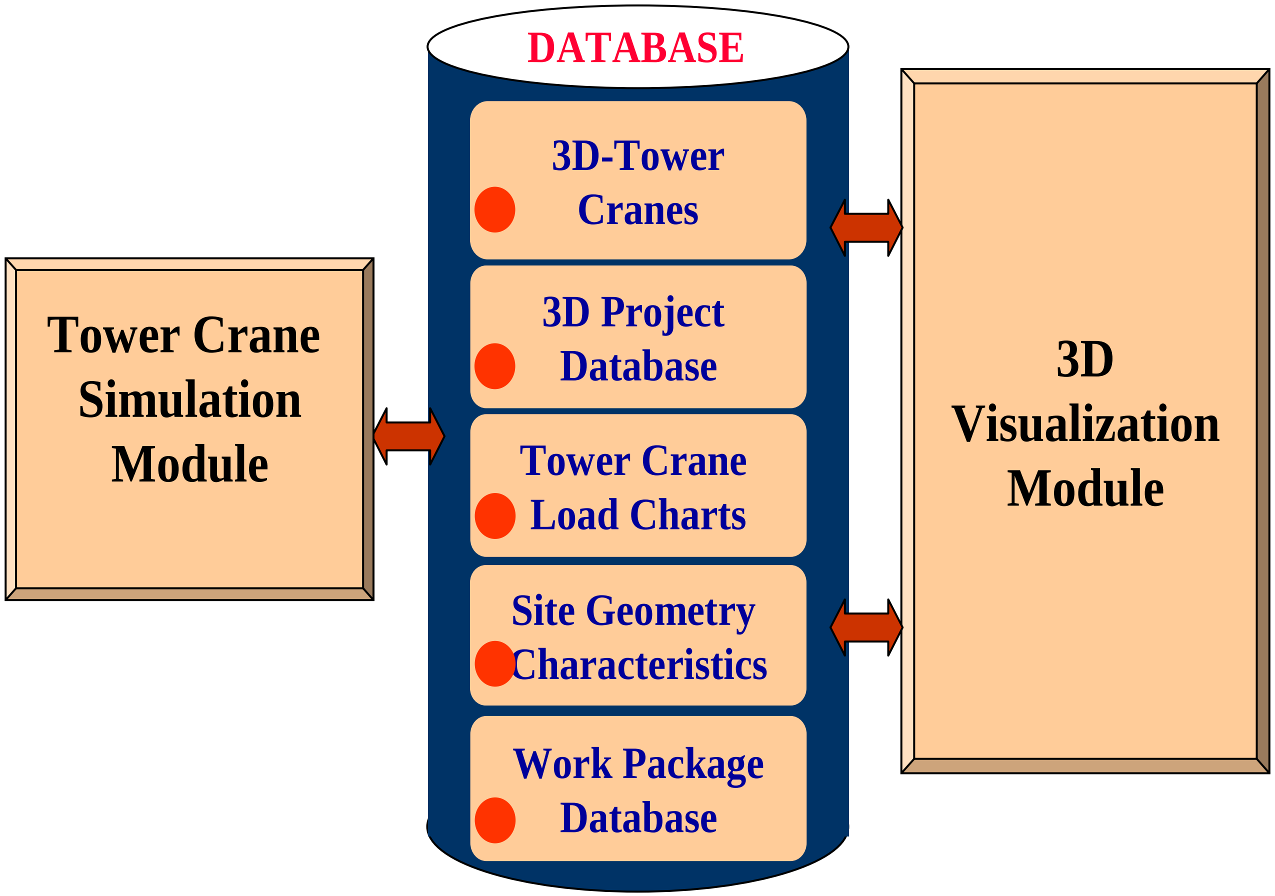
(Kim et al. 2011)

Integrating 3D visualization and simulation for tower crane operations on construction sites

- Computer simulation proved to be an effective tool for aiding practitioners in modeling complex construction operations.
- However, the use of simulation as a construction planning tool has fallen far below its maximum potential.
- The aforementioned problems justify the need for support tools that allow construction managers to construct simulation models and analyze results for themselves.
- Special purpose simulation (SPS) and 3D visualization of simulated operations are two potential means by which this goal can be achieved.

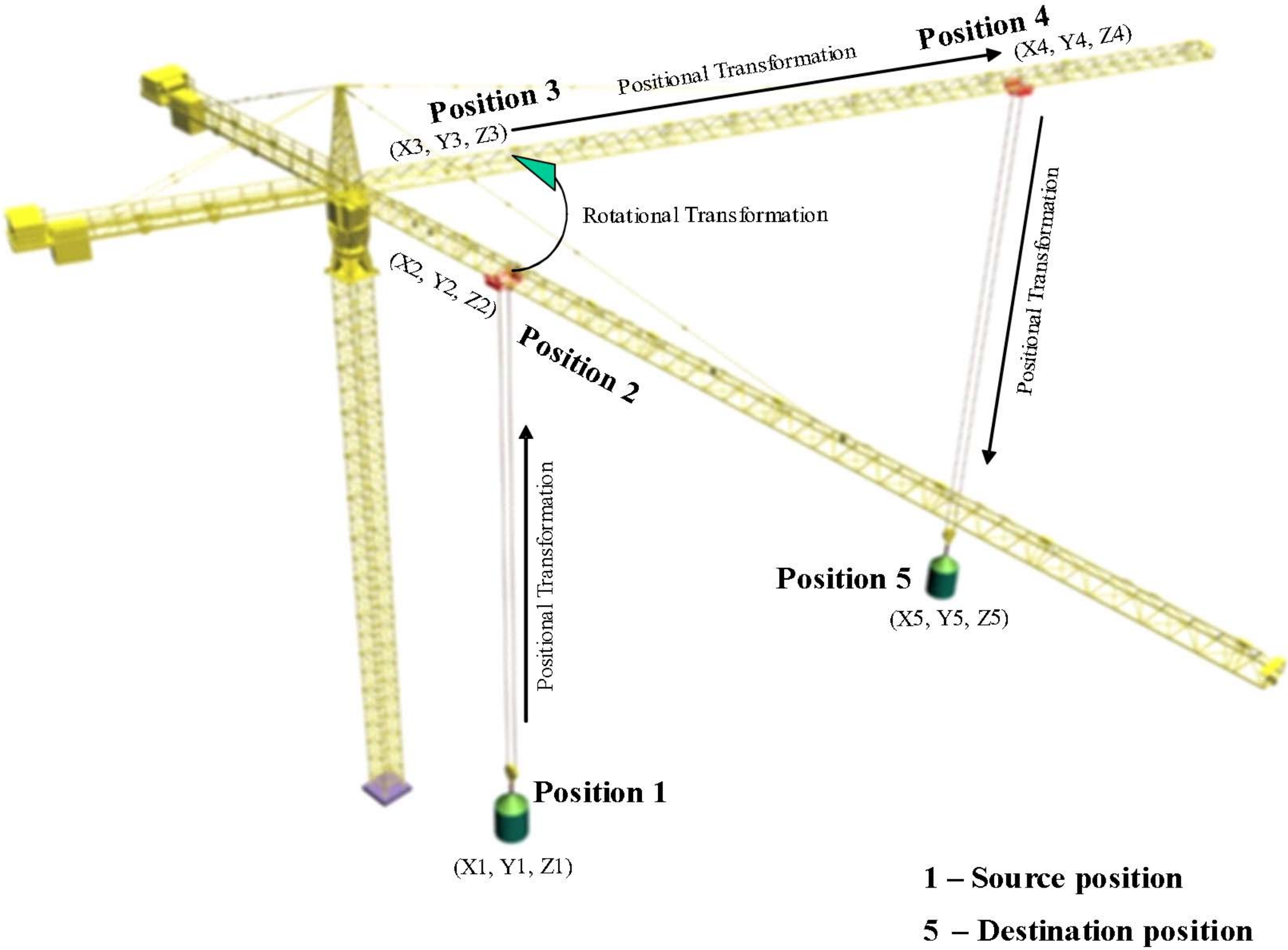
(Al-Hussein et al. 2006)

System Components



(Al-Hussein et al. 2006)

3D Transformations of Tower Crane



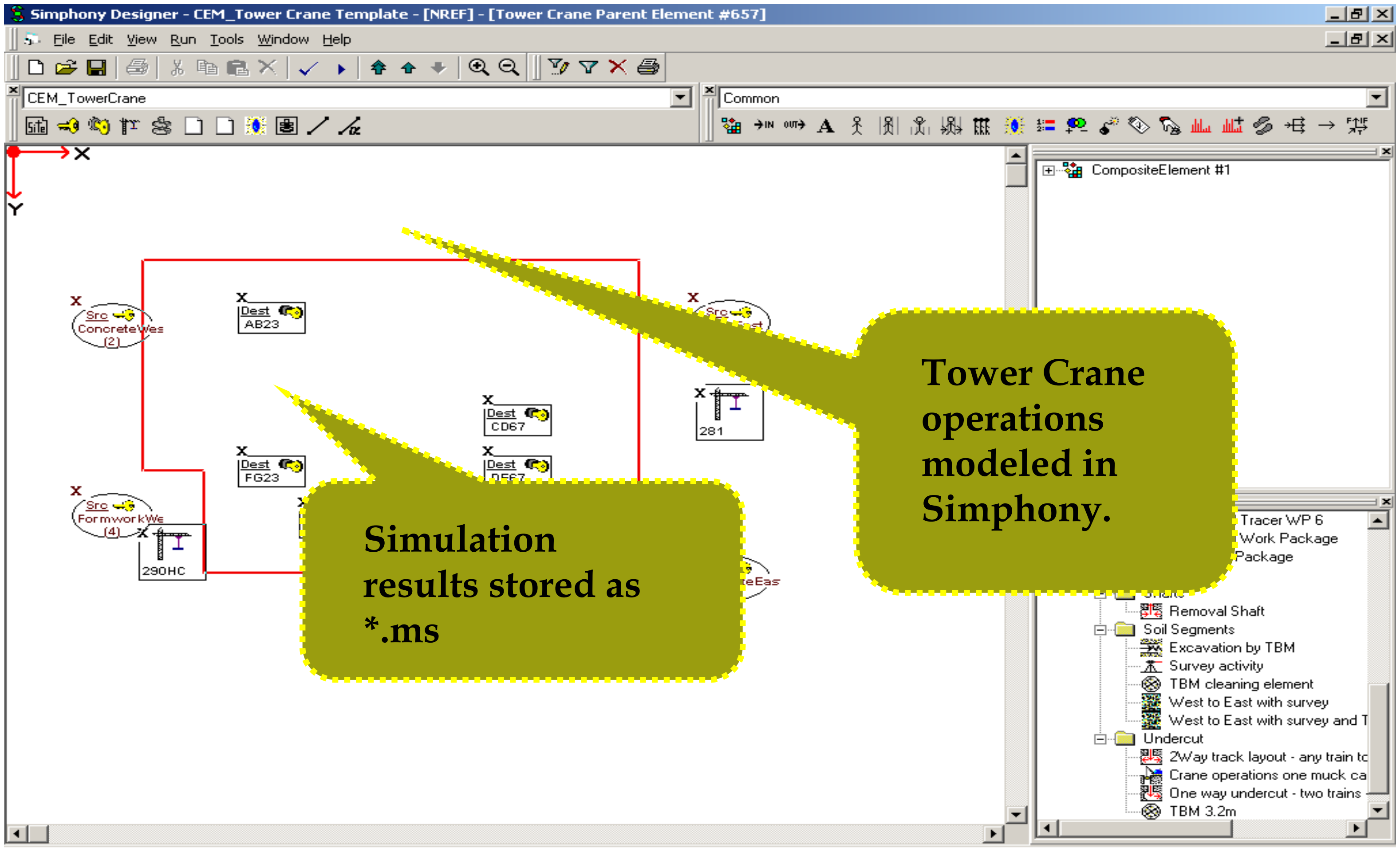
(Al-Hussein et al. 2006)

Case Study

Natural Resources Engineering Facility (NREF), Edmonton

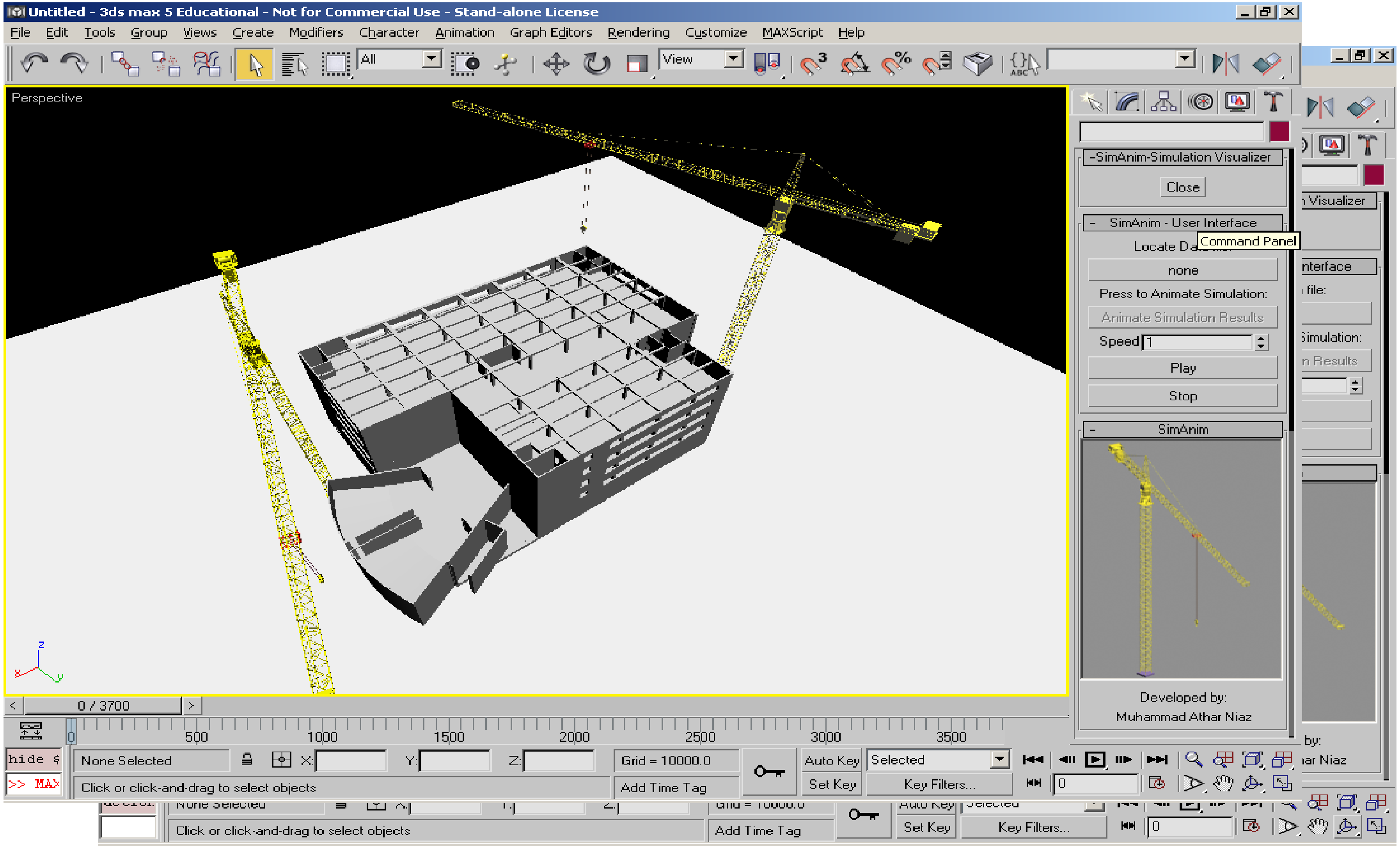
(Al-Hussein et al. 2006)

Simulation in Simphony



(Al-Hussein et al. 2006)

SimAnim – 3D Studio Max



(Al-Hussein et al. 2006)

References

- http://en.wikipedia.org/wiki/Building_Information_Modeling
- Bilal Succar (2009) “Building information modelling framework: A research and delivery foundation for industry stakeholders.” Automation in Construction, 18, 357-375
- http://en.wikipedia.org/wiki/Industry_Foundation_Classes
- Changyoon Kim, Hyoungkwan Kim, Taekwun Park, and Moon Kyum Kim (2011). "Applicability of 4D CAD in Civil Engineering Construction: Case Study of a Cable-Stayed Bridge Project" Journal of Computing in Civil Engineering, 25(1), 1—9.
- Jung Jun Park, Byungil Kim, Changyoon Kim, and Hyoungkwan Kim (2010). "3D/4D CAD Applicability for Life Cycle Facility Management" Journal of Computing in Civil Engineering, (Accepted).
- Taekwun Park, Moon Kyum Kim, Changyoon Kim, and Hyoungkwan Kim (2009). "Interactive 3D CAD for Effective Derrick Crane Operation in a Cable-Stayed Bridge Construction" Journal of Construction Engineering and Management, 135(11), 1261—1274.
- Mohamed Al-Hussein, Muhammad Athar Niaz, Haitao Yu, and Hyoungkwan Kim (2006). "Integrating 3D Visualization and Simulation for Tower Crane Operations on Construction Sites" Automation in Construction, 15(5), 554—562.