The Tower of Babel:
Bridging Diverse Languages with Information Technologies

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Abstract

New digital tools or information technologies are providing the means for architects to realize unprecedented architectural creations. Unfortunately, the promise these technologies hold is far from their potential expression in the built physical environment. A contributing cause to this disjunctive state is the multiplicity of languages and knowledge sets employed by the various team members or actors engaged in a building project. From the cost models of the owners to the shop drawings of the fabricators, each actor views the project in terms specific to their individual discipline. In order to successfully engage the building process, these new technologies must account for this condition and develop means in which to span across traditional boundaries. This paper will examine the disjointed and fractured nature of the building project and identify opportunities for the deployment of information technologies to bridge boundaries, ultimately providing for and delivering architectural projects of unparalleled precedence. Specific aspects inherent to these technologies will be examined to understand where their application may benefit the building process. The key attributes this paper will focus on include: visualization tools, centralized database, cross discipline platform tools and novel forms of information representation. A case study of an architectural project will serve as the means in which to study the successful implementation of these attributes and their resulting impact on the design process and building project. This study will demonstrate how information technologies can be implemented within the multifaceted framework of conventional building projects to yield a project of unprecedented form.
Introduction

There has been much written lately on the promise new digital technologies hold for the architectural and building industry. For the most part these writings have focused on individual technologies isolated in effect from the broader architecture, engineering and construction industry and the processes involved in a building project. Instead of focusing on a specific technology, this paper will examine how information technologies as a whole can be implemented within the overall building scheme to enhance the process and the end product. To facilitate this study, the process involved with the development of an architectural project will be examined to highlight where opportunities lie to employ these advanced technologies.

The paper will use as a point of reference the case study of a mass transit building project. This project is a subway station that forms one component of a comprehensive urban infrastructure project for the extension of an existing mass transit rail system. Several aspects of the project will be examined to illustrate how information technologies were instrumental in its development; how these technologies facilitated collaboration between a diverse group of team members engaged in the building project and at what points these technologies were introduced to enhance the process as well as the project. This paper will demonstrate that through the successful implementation of information technologies the project benefits through collaboration and efficiencies gained through the work process resulting in added value to the end product.

Constraint Modeling

The commission for this particular project was won through a competition. Prior to the initiation of the competition the project had been developed through 30% design documents. The winning architects proposed an unconventional scheme that literally opened the subway line and station to the adjacent urban surroundings. This strategy revealed the inner public workings of the station and linked them to a broader urban public context. Prior to the competition only two-dimensional forms of representation had been generated for the 30% design document phase; there was not a comprehensive 3D computer model of the project or of the site to that point. Due to the complexities of the site in terms of urban infrastructure networks and the desire to link the public functions of the station to the broader public of the surrounding context, the architects felt a 3D computer model was necessary to gain a better understanding of the existing conditions in place.

The ensuing 3D computer model initiated by the architects modeled both the physical features and associated constraint envelopes of the site. Constraint envelopes refer to spatial zones whether occupied or not that are inherent to specific urban networks. For instance, not only was the rail line modeled but also the dynamic clearance envelope associated with the rail line. This envelope maps the spatial zone associated with the train car upon which nothing can encroach. This strategy for modeling extended to the streets and associated vehicular traffic zones, pedestrian zones and even to utility infrastructures and what were termed ‘no fly zones’, areas where potential utilities could be inserted in the future. The site consists of multiple layers of urban infrastructure networks that require mediation for the functionality of the station. With the physical features of the site and its constraints modeled, it became clear where opportunities lie.
for the station to engage the adjacent surrounding context. Initially the constraint model served as a means to identify vertical circulation zones to move people from street level to platform level. As the model developed it was instrumental in organizing and articulating pedestrian flows in and around the station. Not only did it describe how to interface with the surrounding public networks, but also how the project could articulate and enhance these public networks. This process continued which ultimately led to strategies for the organization and configuration of the station.

The constraint modeling process was also instrumental in gaining consensus among the various actors engaged in the project. It enabled discussions between the surrounding stakeholders, the client and engineers with respect to various site and project development issues. Each team member came to the project with their specific interests and concerns and a bias towards understanding particular aspects of the station. The interests of the stakeholders lie in the amenities and benefits the station could provide to the surrounding area while the engineers focused on the functional aspects of the project and the client straddled both concerns. The computer model was instrumental in describing various issues related to the station in terms that were clearly understood by all parties. The computer model was able to illustrate how issues inherent in the site and the functional requirements of the station would precipitate particular design strategies. In turn these strategies were developed through collaboration with the various team members. This enabled the team members to participate in an active dynamic relationship as opposed to passive bystanders which is typically the case (Boland, Lyytinen and Yoo, 2002). In this manner the process somewhat differed from the conventional project approach where the architect imposes their vision upon the project team. Instead the computer model fostered an atmosphere of collaboration between team members that allowed the project to be borne from the constraints of the site, the expectations of the client and stakeholders and the functional requirements of the station.

Centralized Database

As the design for the station progressed the project grew greater and greater in complexity. This resulted in an increase of engineering disciplines engaged on the project. This condition placed a critical emphasis on the ability to share information between team members to enable project development. Initially this process was cumbersome and prohibitive in some respects, due to the techniques used for information exchange. There are two factors that led to difficulties for sharing information between engineering disciplines; two-dimensional forms of representation and site coordinate systems specific to each discipline. Two-dimensional forms of representation tend to generate gaps in information (Boland, Lyytinen and Yoo, 2003). Their form results in discontinuities of understanding within
in overall continuous body of information. Instead of describing an overall form, information is only identified on a two-dimensional plane. In addition there is a systematic methodology that drives where slices of information are taken or where two-dimensional planes interface with the object of inquiry. Typically these planes or section cuts are oriented perpendicular or parallel to the major axis of the work assembly. If the associated work between two separate engineering disciplines is not in alignment these section cuts will not be coplanar.

This last issue couples directly with the use of coordinate systems that are specific and unique to each engineering discipline. This uniqueness does not allow for a common language or syntax in which to share information, but instead views work associated with each discipline in terms specific to that discipline. Roadway engineers used the centerline of road as a reference in which to generate and understand their work with respect to the site. The centerline is divided into equal intervals. Locations and measurements are then understood in terms of intervals along and perpendicular to this centerline. It’s as if one took a three-dimensional Cartesian grid and warped it to follow the road. This system is then also used in determining the orientation of two-dimensional section cuts. To be consistent with the system all sections are cut perpendicular to centerline of road.

The tunnel engineers employed the same methodology for describing information as the roadway engineers, however their reference system was based on the centerline of track. At this particular site centerline of road and centerline of track did not fall into alignment, nor were they parallel. Section cuts by the roadway engineers did not correspond to nor were they coplanar with section cuts by the tunnel engineers. This made sharing information between the two disciplines problematic. Even though the methods of describing information were consistent between disciplines, the reference system employed by each differed which led to difficulties in the exchange of information. Since the scope of work associated with a specific discipline was developed within their own unique coordinate system, understanding relational issues between work products was difficult at best.

The computer model was instrumental in spanning these boundaries. The computer model served as a centralized database that gathered information generated from each engineering discipline. Information between disciplines was treated in a consistent manner which eliminated any biases in its description. The 3D capability of the computer offered the advantage of modeling physical objects or systems in their entirety, eliminating partial or piecemeal descriptions inherent to 2D representations. This was a major asset in terms of understanding the various systems and their relationships. With the entirety of all pertinent physical systems modeled in a uniform coordinate system, inquiries into relational issues could now be performed. This was instrumental in understanding potential conflicts or interferences between engineering work assemblies. This capability also provided for a much tighter integration among the various systems of the station. This approach enabled the computer model to act as a boundary object; introducing a common language or syntax that provides for the sharing of information across boundaries (Carlile, 2002). Now, instead of multiple information sets particular to each team member, one database could be shared in a collaborative manner for the development of the station. The data could be accessed and modified as required. It could be used to analyze and coordinate relationships between various engineering work assemblies.

![Figure 4. Plan drawing of site, dashed gray line is centerline of road, dotted lines are centerline of track.](image-url)
Cross Platform Tools

With the development of the project came the greater need for more specialized information which resulted in an increase of engineers representing diverse fields of interest. To satisfy criteria with respect to each engineering discipline, it was necessary to view the project in a variety of terms meaningful to each. Therefore, the project takes on a number of different meanings that correspond to the various disciplines. This condition can be considered a difference in semantics among various parties viewing a common language. Whereas in the previous example a common language allowed for the exchange of information amongst a diverse audience, semantic differences account for different interpretations of that common language (Carlile, 2002). For instance, as the project developed, smoke evacuation became a critical factor for the functionality of the project. This meant that the station needed to be viewed in terms of its behavior with respect to fluid dynamics. This represents a very specific set of terms and criteria for the evaluation of the station. These terms contrast sharply for instance with the terms a structural engineer employs to evaluate the station.

In the conventional method of project development, sharing information between disciplines would ultimately mean recreating the project from scratch in terms specific to a particular discipline. The computer software that was employed for this project avoided this scenario. The software used for the project was Rhinoceros which lends itself extremely well to cross platform sharing between disciplines. Instead of each team member generating a database from scratch specific to their discipline, the existing Rhinoceros database could be easily translated into terms that were meaningful to each. This represented a major time saving procedure and made information sharing between disciplines a seamless matter.

The use of the Rhinoceros software was very instrumental in the development of the project. This ability to easily share data between various disciplines had two effects: 1), an iterative process for the development of the station unfolded in contrast to the conventional linear process and 2), the team members collaborated in a much more participatory dynamic manner than the passive neutral relationship which is typically the case (Boland, Lyytinen, Yoo, 2002). The iterative process allowed for design strategies, in contrast to set and unyielding design solutions to tackle the many issues encountered with the development of the project. In this way it differed from the conventional design approach which is characterized by a linear process of development. This linear process of development implies that the outcome of the design is known in advance and that the development of the project merely consists of the motions of moving from point A to point B. This method of development however is very unforgiving when unforeseen conditions are encountered. This process precludes possibilities or opportunities that may arise over the course of development for the project. It also preempts the ability of team members to actively contribute to the design development process. On the contrary, an iterative process allows the design to evolve in relation to a number of factors influencing the project, whether they stem from the physical attributes of the site, the functional requirements of the project or various concerns of the team members. As issues or conditions arise over the course of development, design proposals can be quickly modeled and in turn translated for analysis and evaluation by the respective engineering disciplines. This process continues until the various conditions or issues associated with the project play themselves out and ultimately reach a state of resolution.

For this iterative process to occur, the team works in a much more integrated and collaborative manner; team members are actively engaged instead of neutral bystanders (Boland, Lyytinen...
This allows for the various disciplines to influence the design of the project. As issues arise or conditions develop, they can easily be evaluated, assessed and rolled into the design of the project with this process. For instance, if through the fluid dynamic analysis, information is gained that requires the modification of particular surfaces to aid in the removal of smoke, this information can be input back into the design model for alteration. Once the design model is altered, these modifications can then be brought back into the fluid dynamic model for furthering testing and analysis until the model performs within acceptable criteria limits. This process continues in each discipline until resolution is reached for the various issues affecting the station. The greatest benefit this process yields is a much more integrated project between the various systems that constitute its form. Since the project essentially is a compilation of systems, this iterative process allows for a much tighter integration of these various systems. This is the added value the iterative process contributes to the project. The cross platform sharing of information between disciplines allows the project to reach a much higher and sophisticated level of development.

Figure 6. Computational fluid dynamic (CFD) model screen capture illustrating smoke layer with smoke exhaust system off.

Visualization Tools

In addition to the tools afforded by digital technologies noted earlier, the computer also offers unique visualization capabilities. It can filter and describe information in a number of different formats. Just as a spectrometer can identify different element compounds invisible to the naked eye, so too can digital technologies foreground particular information that is relevant to a project. This becomes extremely useful in conversing with diverse groups of people. Again it allows for a common understanding of information among various team members. This ability became extremely important for this particular project. Due to the complexities of the site and program and their interrelationships, issues of project configuration and constructability became driving factors for the station. It was incumbent upon the station to mediate a number of conditions that varied from street level down to platform level. These conditions suggested forms that are not conventional in the construction industry.

The construction industry favors forms that are orthogonal due to a number of factors stemming from industry standards of manufactured products (straight runs of steel) to conventions of assembly in the field. These factors coalesce to create a bias in the construction industry towards rectilinear forms. The complexities of the site and the misalignment of the street and rail line below did not lend itself well to a rectangular form. Several problems were encountered with the ability of a rectilinear form to negotiate the specifics of the site. To satisfy these conditions a simple geometry in the form of a cylinder was proposed. The cylinder served as the controlling geometry for the exterior envelope of the station.

Figure 7. CFD model screen capture illustrating design fire and associated temperature ranges.
What made matters unique is that only a very small portion of the overall geometry comprised the envelope of the station. In addition that portion that constituted the envelope did not follow the dominant ruling lines of the geometry but was situated off axis. It’s as if someone took a cardboard tube and cut a small piece out that was not perpendicular or symmetrical to the length of the tube; the resulting piece would appear skewed and irregular. When the station envelope was viewed alone it appeared complex since the simplicities of the overall controlling geometry were not evident. Typically a proposal like this would meet resistance due to the unorthodox use of a unique geometry and the associated constructability issues. Issues of costs in relation to unique framing members, forms of fabrication and assembly would immediately be cited. However the visualizations tools provided for by the computer were able to circumvent these arguments. When the constructed portion of the frame was shown to be part of a larger regular geometry, it could be demonstrated that the framing members were consistent and based on a single radius. Not only were the framing members consistent but also all the cladding and connection details. This proved to be not only feasible but cost effective, due to efficiencies gained through the use of a cylindrical form which has less surface area than a corresponding rectangular form, and therefore less materials and weight associated with the structure. The provision of visualization tools by digital technologies allowed this to be demonstrated across a broad audience, from the client through the engineers. These visualization tools enabled people from various backgrounds and knowledge sets to understand the value afforded by such an approach. Again it is through the effective deployment or application of information technologies which aid in spanning across knowledge sets of diverse team members, enhancing the project development and hence end product.

Conclusion

These examples have shown how information technologies associated with the new digital tools of the computer are instrumental in the development of a project. As can be seen, the process of design for the station was enhanced through a collaborative team effort created through the use of information technologies resulting in a better end product. The successful deployment of these technologies helped in the restructuring of the conventional working practices of the team calling for tighter relationships between individual team members (Boland, Lyytinen and Yoo, 2002). This collaborative process afforded by information
technologies results in a greater stake in the project by individual team members. This raises the expectations of the parties involved and consequently the design of the project.

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