Designing and Building the new E-line station Den Haag

# From architectural vision to reality

*The light rail connection between Rotterdam and The Hague was using the heavy rail tracks of the Dutch Railway company as a temporary solution. However, in the final situation, a separate platform was required. This paper describes the design and execution of this new platform which was complicated due to the restricted size of the building site and tight time schedule.*

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1 Haags Startstation E-lijn
2 Artist's impression
3 Situation

On August 22nd 2016, approximately 2 years and 4 months after the project was awarded to BAM Infra, the 'Haags Startstation E-lijn' (photo 1) was opened to the public.

Prior to the contracting phase the stake holders, such as the City of The Hague, public transport companies of The Hague (HTM) and Rotterdam (RET), ProRail and various advisors, such as ZJA Zwarts & Jansma Architects and Movares consultants & engineers studied various options and conceived an architectural solution that fitted into the masterplan for The Hague New Central. In the proposed solution emphasis was given to transparency and slender curved shapes. This architectural design was the basis for the public procurement of the project. (photo 2).

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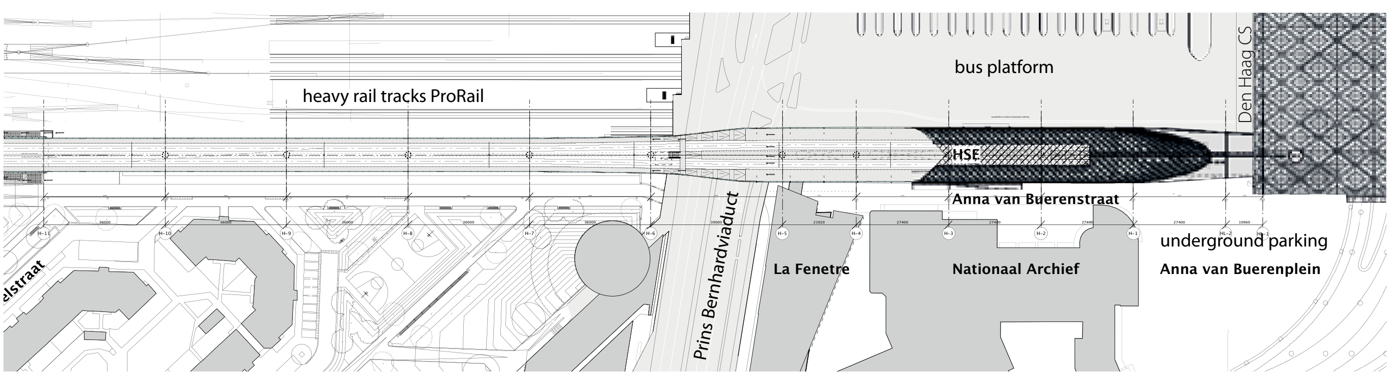
In the phase prior to contracting it was determined that the station should be located on level 2, above the existing train station (level 0) and the bus station (level 1). This decision was driven by the lack of space for a new light rail station in between the existing station, bus platform, underground parking in the Anna van Buerenstraat and other existing structures (fig. 3).

At the location of the station a 323 m long viaduct through the Anna van Buerenstraat passing over the Prins Bernhardviaduct into the Laurens Reaelstraat was required. The passage over the Prins Bernhardviaduct with a 4.70 m clearance determines the level of the station. After this passage the rails lower to ground level with a 3,75% slope. Figure 4 gives an overview of the project. The first part of structure consists of ground works, an U-shaped concrete structure filled with sand on deep foundations and an abutment. The second part consists of a steel deck supported on 10 steel columns supported by concrete bases on deep foundations. The last column is attached to a services building where passengers can access the bus platform or the train terminal. The last part of the steel deck is wider and is provided with a roofing of steel beams and glass. In this part of the deck is the platform where passenger can enter and leave the light rail wagons.

The reference design of the Client contemplated a viaduct with 10 separate steel spans varying from 22 m to 36 m placed on top of steel columns. Especially in the narrow Anna van Buerenstraat various problems had to be overcome. First of all this street had to stay open to traffic during construction because of the exit from the underground parking. Passenger streams towards and from the station had to be allowed and also access for the emergency services had to be ensured. However, a major part of the structure would have to be assembled over this street (fig. 3). Additionally both the bus station floor (rail station roofing) on one side and the underground parking on the other side had limited weight carrying properties which limited heavy lifting possibilities around the Anna van Buerenstraat.

In cooperation with co maker Iemants Steel Structure, BAM Infra opted for an important design change during the tender phase. It was decided to convert the 10 single span Client's design into a continuous bridge deck of 323 m which had to be shoved into its final position and would be prefabricated on the other side of the Prins Bernhardviaduct.

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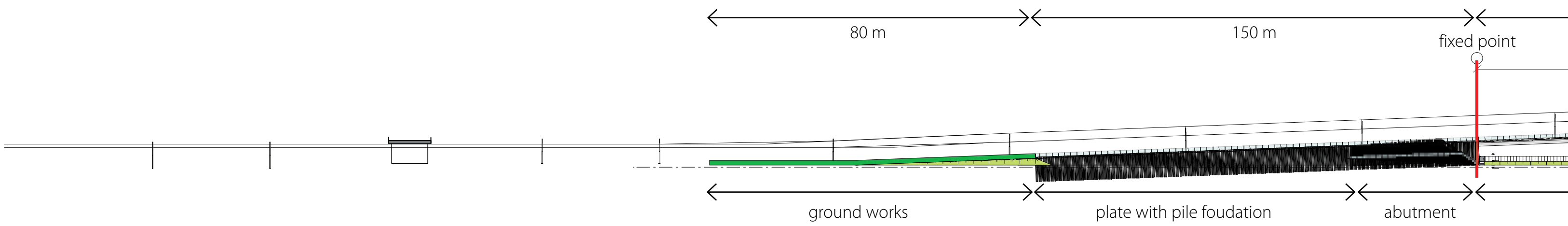
4 Longitudinal section of the project
5 Sequence of deck sections
6 Lifting jacks on right and left side, moving jack in the middle
7 Shoving deck part A over auxiliary structures (blue)
8 Position of bearings in Client's reference design.

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Through this change the safety could be improved significantly and hindrance during the execution could be reduced. The biggest part of the construction activities for the steel deck were moved towards the Laurens Reaelstraat with more space, less passengers and better options for heavy lifting of bridge deck elements. Only the first two deck sections were shoved towards their final position. The rest of the sections were assembled directly on their final position. In figure 5 the process is schematically pictured. First deck part A was assembled on a prefabrication platform. After part A was finished and shoved to its final position, part B was prefabricated on the same platform. After part B was shoved into its final position deck parts C were assembled directly on their final position.

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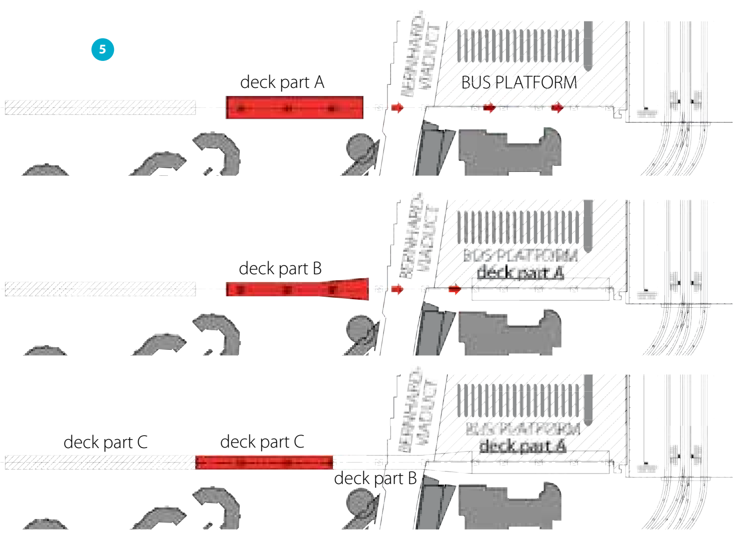


During the process of shoving, the deck was supported alternately by lifting jacks and moving jacks (fig. 6). The jacks were placed on top of an auxiliary structure around each column (fig. 7). When the deck was supported by the jack in the middle the horizontal jacks on each column made a stroke from left to right. When the stroke was finished the jacks on the left and right lift the deck and the jack in the middle was moved back from right to left where the deck was released back on to the moving jack. This way the deck part was moved approximately 2 m during each stroke. During one weekend deck part A was moved over 100 m.

By changing the designed building method some new engineering challenges had to be solved. The continuous span led

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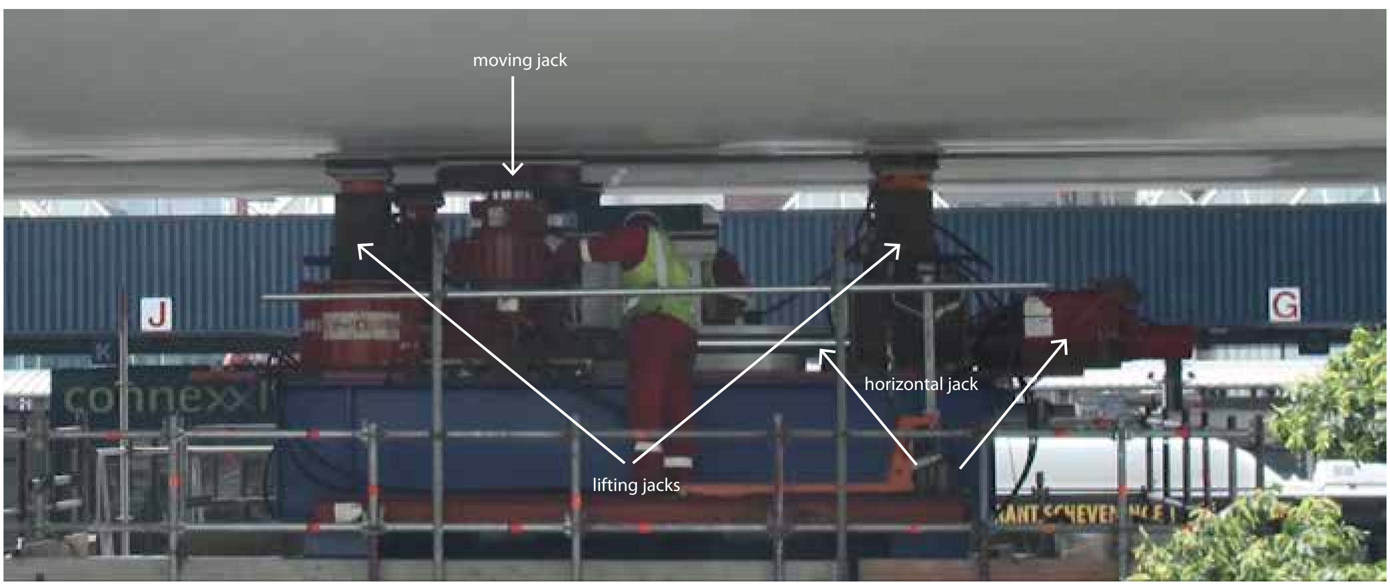

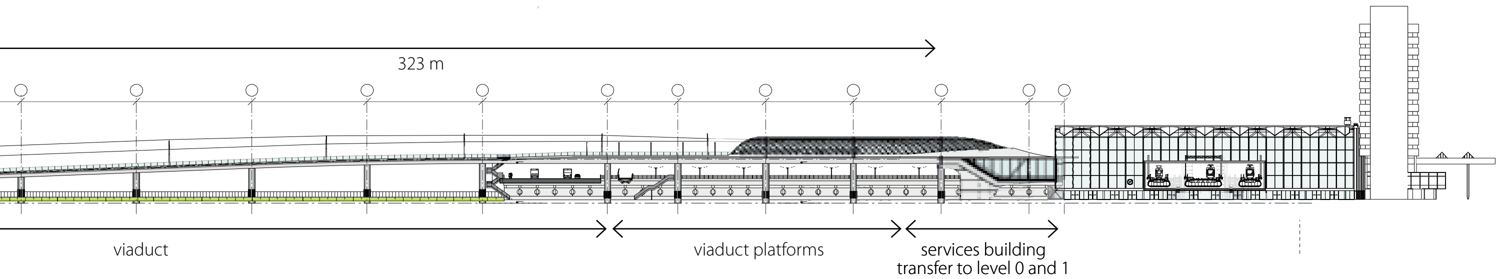


to bigger displacement due to temperature. Also the continuous girder in combination with the slender architectural columns called for special measures to assure stability of the deck. In the Client's reference design the separated decks where supported by a fork shaped beam on top of the columns (fig. 8). In order to shove in the deck, the support width of the deck had to be drastically reduced. Apart from these challenges induced by the design change it was necessary to integrate different parts of the design from different subcontractors into one integrated design solution.

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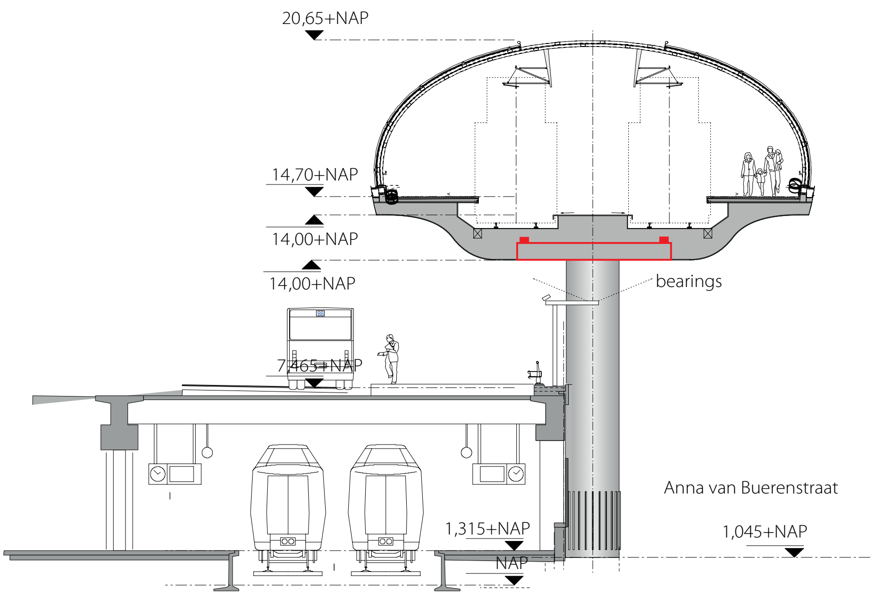
## Displacements

The slender bridge deck is supported by slender columns with a maximum diameter of 2 m. The top level of the rail track in the station is approximately 13 m above ground level. At the start of the viaduct an abutment is projected and on the other end a services building with elevator shaft and automatic stairs are located.

The bridge deck had to have a longitudinally fixed point. Because of elongation due to temperature the other supports had to be provided with sliding bearings. The slender columns with small foundations were not capable of absorbing the summed forces from the friction and breaking forces of the metro. Also the Client did not wish an expansion joint in the railway track. Therefore the fixed point was chosen at the abutment. This choice resulted in ULS-movements of the bridge of approximately 350 mm on the other end where the platforms are located.

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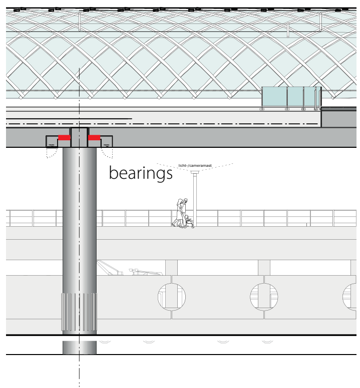
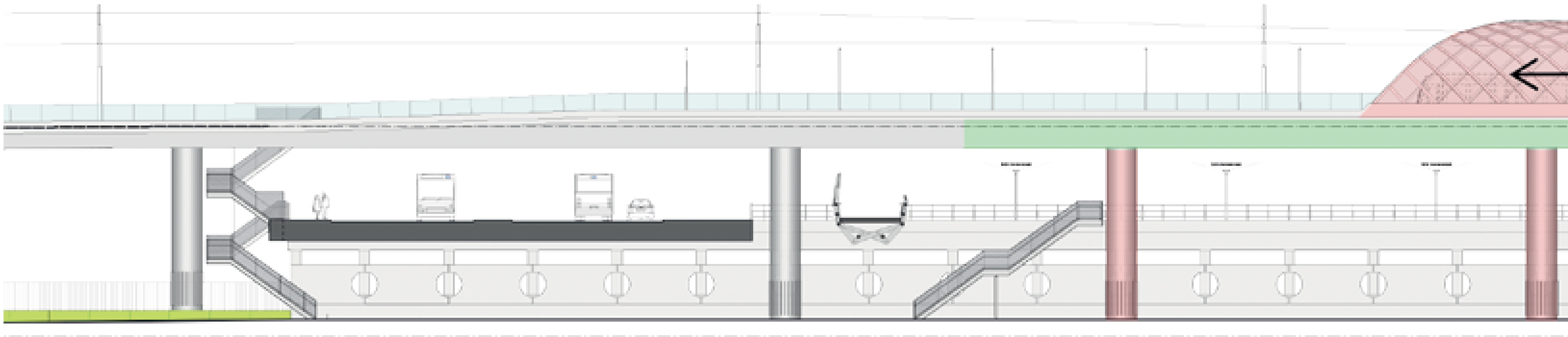


9 Movements of roofing and bridge deck
10 Roofing structure (a) and mock up connection grid beams after testing (b)



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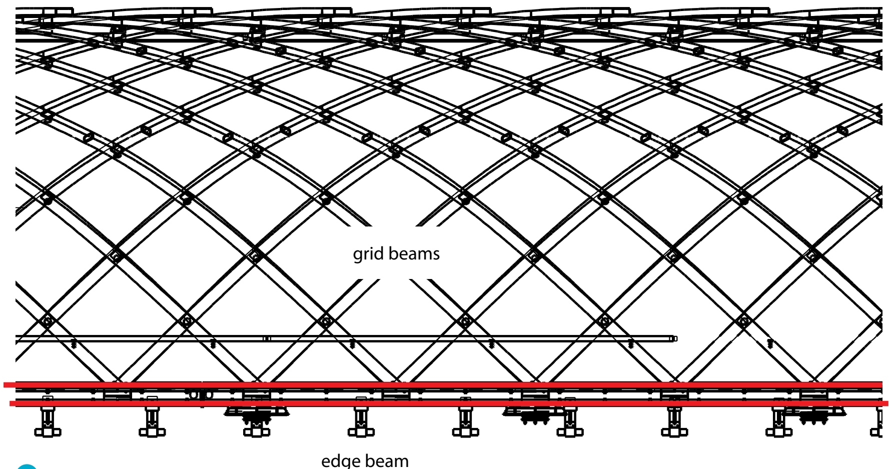


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In figure 9 it is illustrated how the bridge deck slides over the supports on top of the slender columns and how the architectural roofing fixed to the services building (red) is sliding over the bridge deck (green). Therefore, with increasing or decreasing temperature the bridge deck and the roofing move in opposite directions.

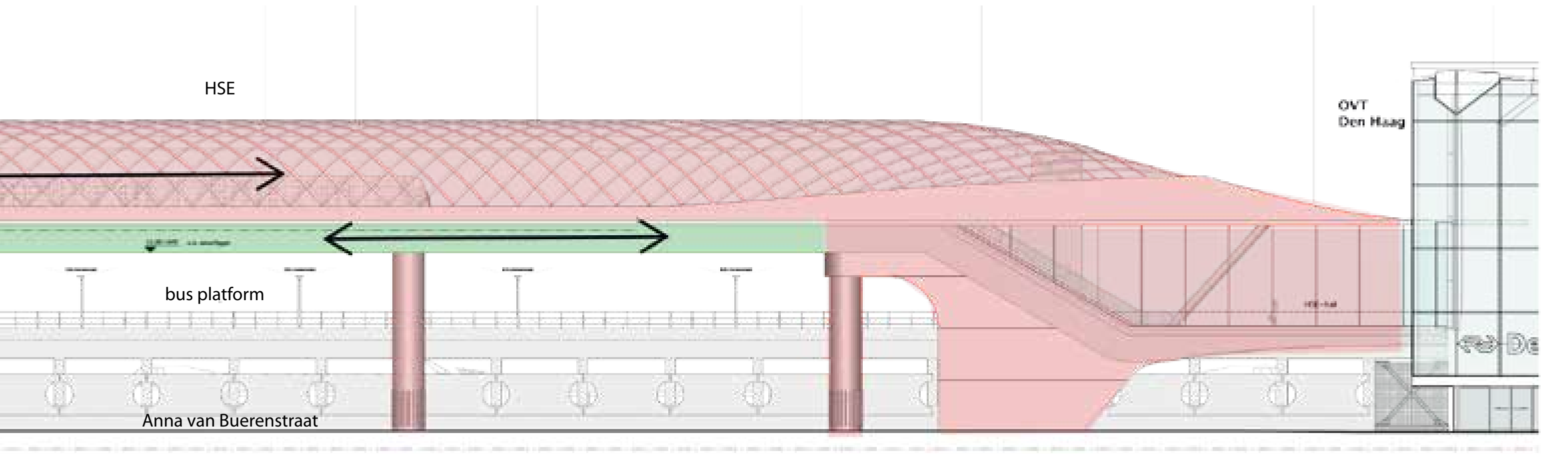
The glass roofing is supported by sliding bearings placed on top of the bridge deck. The roof structure consists of an edge beam and grid beams. The complete structure is hot dipped galvanized. All bolted connections are made on site. The estimated stiffness of this connection was verified by building and testing a mock-up of this connection (photo 10b).

## Integration

Aside the challenges that resulted from the design change, the architectural requirements imposed another challenge. The architect made an 'open' design using slender curved shapes. The Client had opted for a design that should be a landmark and it was contractually arranged that all designs and design stages had to be approved by the architect ZJA. The architect was to make sure that the artistic impressions made at the start would be transformed into reality.

From the beginning it was clear that due to the complex three dimensional shapes and the great variety of disciplines a Building Information Model was needed. The model started with the 3D-Design of the architect ZJA and a point cloud of the existing situation. Each design step was checked against this model. Each company worked in its own software application. The different designs were checked with the original visualization and the interfaces between the different designs were adjusted.

11, 12, 13 From design to Building Information Model to reality




Emphasize was given to sharing models as early as possible to get an early insight in possible clashes and the use of limited space. Also, it was a contractual requirement to keep cables, piping and bolted connections out of sight. This resulted for example in a detail in which the bolted connections of the grid beams of the roofing were hidden behind speakers and light spots.

This approach made it possible to stay close to the original visualization (fig. 11, 12 and photo 13), get timely design approvals from the architect and effectively integrate different designs. Also the model was used to gain insight into difficult details preparing the execution of the works.

## Conclusions

The design change that shifted the construction works from the crowded Anna van Buerenstraat to the more spacious Laurens Reaelstraat was crucial for BAM Infra to get the contract.

The use of BIM-technology and the tight cooperation between client, contractors, co-makers and subcontractors were key factors to complete the project successfully and realize the landmark as desired by the client. ☒

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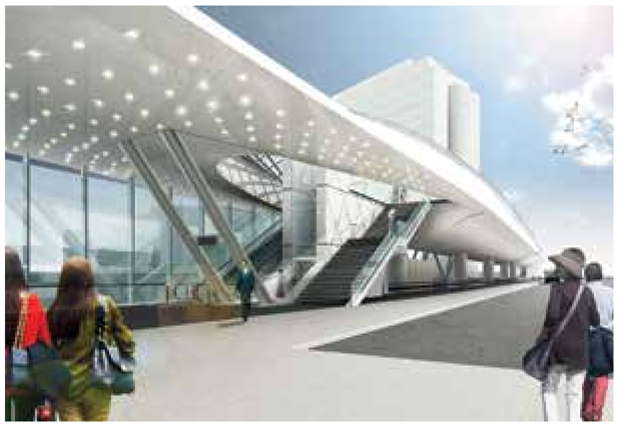

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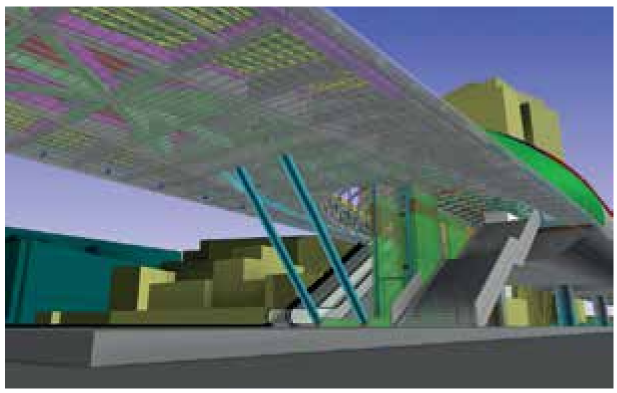

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