JR East started the activities of its group long-term management plan JR East 2020 Vision—Challenge—in fiscal 2008. This plan covers targets that should be implemented with a focus on ten years into the future. It proposes “moving up a gear in seven areas” with “maximum safety levels” as its base, incorporating key phrases such as “increasing focus on investment to raise corporate value”, “opening the way to new business areas”, “upgrading the Tokyo metropolitan area railway network”, and “increasing life services businesses operating revenues to approximately 40% of total operating revenues by fiscal 2017”. To achieve those targets, various railway infrastructure including over-track buildings needs to be developed and restructured. This essay will cover the current state and future outlook of R&D for engineering and architectural space creation that contributes to cost reduction, shorter construction time, quality, and amenity improvement to propel smooth investment and construction for such infrastructure work.

JR East started activities of its group long-term management plan JR East 2020 Vision—Challenge—(GV2020) in fiscal 2008. This plan covers targets that should be implemented with a focus on ten years into the future. It proposes “moving up a gear in seven areas” with “maximum safety levels” as its base, incorporating key phrases such as “increasing focus on investment to raise corporate value”, “opening the way to new business areas”, “upgrading the Tokyo metropolitan area railway network”, and “increasing life services businesses operating revenues to approximately 40% of total operating revenues by fiscal 2017”. To achieve those targets, various railway infrastructure including over-track buildings needs to be developed and restructured. Such important work includes development of structures in over-track space to raise the value of stations, improvement work to raise functionality of stations at terminal stations, and enhancing the railway network in the Tokyo metropolitan area and other areas. Further expansion is necessary in R&D for engineering and architectural space creation that contributes to cost reduction, shorter construction time, quality, and amenity improvement to propel smooth investment and construction. And efforts made up to now will need to be continued.

This essay will cover the current state and future outlook of R&D for engineering and architectural space creation.

GV2020 has “advancing research and development actively” as an ongoing effort. And under that are the four cornerstone themes of “Pursuit of Maximum Safety Levels”, “Enhanced Operation Stability and Reliability”, “Expansion and Creation of New Markets” and “Lessening Environmental Impact”. The space creation R&D fields and key phrases for each of those are given below (Fig. 1). Fig. 2 shows the short-term, 10-year, and future-oriented timelines as well as portfolios separated into business issues, issue solving, and proposal categories.

Fig. 1 GV2020 and Future Space Creation R&D
In this issue of the JR East Technical Review we cover four technical fields. We introduce "development of escalators with aseismic functions" as R&D success for (1) Safety Improvement, along with "displacement suppression management methods for construction of underpasses under tracks (COMPASS method)" and "countermeasures for track deformation in summer construction" as R&D for controlling track deformation in construction. For (2) Reliability, we introduce "improvement of quality of structures and reduction of maintenance by surface impregnation materials" and "creating highly functional concrete with self-healing concrete" as R&D contributing to building durability and quality improvement. For R&D on (3) Market Expansion including Over-track and Terminal Station Development, we introduce "new frame building method for reducing costs of buildings over tracks", "seismic response reduction frame building method for the total station building system that uses added-on buildings", and "small-diameter cast-in-place piling method for narrow spaces such as inside stations". For (4) Preservation of Environments Globally and Along Lines, we introduce "conventional line railway noise at high spaces", and "design and construction methods for foundation vibration countermeasures".

I will now show roadmaps for each of the four technical fields, covering the direction of future R&D while giving an overview of current R&D. We will go forward with efforts to achieve the goals for GV2020, taking into account the status of project progress and technical issue difficulty/time to solve/priority, R&D resources, non-JR technical trends and other issues. This will be done while making additions and revisions as necessary.

(1) Earthquake protection measures for structures and securing safety in train operation (Fig. 3, Fig. 4)

1) Structure safety improvement and earthquake protection measures

(1) Aseismic reinforcement/earthquake protection measures for existing structures (civil engineering)

We have hitherto completed or are working on civil engineering structures with priority on aseismic reinforcement of shearing rigid-frame viaducts and piers with a high probability of collapse for the Shinkansen and areas such as south Kanto and Sendai. Technical development of various aseismic reinforcement methods has being done where cost reduction for construction countermeasure expenses and effective construction in various construction environments such as viaducts in use is possible, and those are being universally applied. There is also a plan for strengthening columns and piers on the bending and shearing boundary and for raising the strength of unreinforced concrete and various other structures, to improve aseismic performance of railway structures as a component line of the railway network. R&D is also ongoing to carry out countermeasure construction in a streamlined manner when implementing that plan. From a mid- and long-term perspective, construction methods will likely need to be developed compatible with cost curtailment in countermeasure construction for various structures (retaining structures and others built long ago).

(2) Aseismic reinforcement/earthquake protection measures for existing structures (architectural)

The Seismic Retrofit Promotion Law (for specific structures of three floors or higher and 1,000 m² or more) came into effect in 1995 and an advisory (for stations with average of 10,000 or more passengers
a day and having turnaround facilities or connections to other lines) was issued from the Ministry of Land, Infrastructure, Transport and Tourism in 2005. Aseismatic reinforcement is promoted for station buildings, over-track stations and station buildings connected with commercial buildings that those apply to. Over-track station aseismatic reinforcement construction using adjacent buildings and construction using lifts having new aseismatic reinforcement are examples of technical development success in making such aseismatic reinforcement construction more efficient and reducing costs. Also, we are proceeding with R&D on column-base reinforcement methods. These methods secure aseismatic performance equivalent to that of the current law (application retroactively to existing structures) when adding over-track stations buildings and other facilities annexed to existing station buildings and the like (when existing non-conforming buildings are from before the 1981 revised Building Standards Act).

2) Securing safety in train operation
For further improving safety in construction near tracks, we developed a track deformation control management method based on various measurement results at the site of construction done with the already-developed COMPASS method. The purpose of that is to further improve track deformation control when excavating with that method. And after a major transport disruption in 2006 at a work site using the HEP&JES method, we are proceeding with technical development for improving the conventional HEP&JES method based on the decision by the company construction of underpasses under track safety committee. This means also looking at development to improve construction beams that contribute to shortening construction times while confirming the advantage of a composite construction method that combines use of construction beams used in open cut construction. Such development predicates the perspective that shortening construction time for safe and stable transport is necessary to avoid risk.

In view of the Shinkansen derailment accident in the October 2004 Mid Niigata Prefecture Earthquake, measures such as L-shaped rolling stock guides have already been introduced. As other measures, R&D is ongoing for impact-compatible platforms that ensure safety of running trains and conversion of turnouts on earth beds to those on concrete slabs.

(2) R&D for improving reliability and quality of structures
(Fig. 5)
1) Structure quality improvement
Work standards that give new observations on preventing peeling and flaking related to concrete structure quality have undergone multiple revisions. However, the necessity for controlling cracking of concrete right after construction has been attracting attention in recent years. Concrete shrinkage becomes large and cracking that affects durability occurs for a variety of reasons. Those include structural forms where restraints for reinforcement need to be larger due to issues such as physical properties of coarse aggregate and structural plans resulting from conditions for securing earthquake protection and construction environment/location. For that reason, we started research on advancement of design to control cracking.

2) Construction/structural technology contributing to asset management
Deformation of general concrete structures is classified as initial defects, damage, and deterioration. However, dealing with deterioration of structure’s functions over time upon maintenance and management is important in asset management. In light of that background and referring to Guidelines for Design and Construction for Surface Protection (Draft) (Japan Society of Civil Engineers, 2005), we are conducting research on specifications and other items that should be heeded as a railway business provider for construction in application to new structures. Furthermore, we are conducting R&D on construction specifications and other items based on quantitative identification of water absorption control effects for existing structures applicable to various surface conditions. Construction quality also must be sound at time of construction in order to curtail maintenance and management effort and expenses for concrete structures. And we have started R&D from the foundational level for methods to recover quality if construction quality is insufficient in places. We expect that the accomplishments of the R&D will contribute strategic asset management for to life cycle assessment (LCA) and structures.

3) Technology for visualization of the inside of structures etc.
Quality of new structures is secured through strict and appropriate implementation of quality control by the workers fulfilling the order (contractor) and completed construction inspection (receiving inspection) by the ordering party (supervisor). Confirmation is necessary during construction of interior parts such as reinforcing bars that are no longer visible after construction. Furthermore, a more efficient design and construction process can be expected for improvement, rebuilding, and other work for existing structures if the amount and shape of steel for reinforcing bars and frames can be accurately identified. Nondestructive methods of identifying the layout of reinforcement often used include exploratory measurement by electromagnetic radar and electromagnetic induction. But three-dimensional and accurate measurement (location and quantity of reinforcement) and visualizing and imaging are difficult in normal inspection methods. For that reason, there is demand in the industry for nondestructive diagnosis technologies. So, we plan to...
start basic research on application of those to structures while looking at tie-ups with organizations that have cutting-edge exploratory technologies.

Furthermore, there is much demand for in-ground visualization technologies that can accurately identify at the construction planning stage obstructions, buried objects, and the like at in-station excavation and under-track construction. So, we plan to work on application of those to construction as a future-oriented theme.

4) Making higher quality construction systems utilizing ICT

Increases in quality and innovations in technology are going forward for the construction worksite through information communication technologies (ICT). For example, R&D is being done in the construction industry on building information modeling (BIM) for general private-sector buildings. BIM is a method by which management and quality of design, constructing and maintenance are linked by forming buildings and structures by a design process of forming a database from 3D models (CAD). Such data is used to identify design and structure detail problems (front loading) before construction and to share completion images at design and construction phases to help in areas such as improving quality and productivity.

Many departments and personnel are involved in construction and improvement projects from the planning phase through survey, design, construction and maintenance/management after delivery. Also, many types of work and specialized work make up each construction process. Communication between main parties involved through visualization 3D models can be imagined for making higher quality structures. And linkage with ITC such as visualization, wireless communications, RFID, and nondestructive technologies also can be assumed to be effective. Furthermore, improvements and development in construction systems utilizing ICT to directly link to the mechanism of performing work and correspond to railway construction are thought to be needed, so we plan to look at this as a mid- to long-range R&D theme.

(3) R&D to support market expansion such as improvement of over-track buildings and terminal station facilities (Fig. 6 to 9)

1) R&D contributing to promotion of infrastructure formation and over-track space building projects to improve functionality of station spaces

We assume the following themes to be technical development contributing to cost reduction and shorter construction time by modifications to aspects such as design planning and construction planning.

1) Themes related to construction methods

A large amount of track protection work is involved in pile construction within stations, above platforms, and between tracks, so track protection reduction and performing construction both during day and night could greatly curtail construction expenses. Currently, we are working on this issue with JR East divisions in charge of construction with a goal of application to station renovation and station building reconstruction work requiring large piles of around three meters in diameter. Furthermore, pile construction from above the track and medium and small diameter pile group foundations could be useful in some situations depending on the construction environment and structure plan. We recognize development of such design and construction methods important. And we plan to follow up on deployment of construction methods allowing pile construction by small construction machinery in open cut construction within stations and platform improvement covered in this issue.

2) Themes related to structure form, structure plan, and introduction of new materials

There are advantages to structural systems whereby introducing damage control mechanisms (architectural structure system controlling building damage in earthquakes using seismic isolation structures and damping structure) to buildings above tracks has damage from load in an earthquake concentrated in specific sections to distribute the load over the entire structure system. Thus, construction expenses are expected to be curtailed compared to conventional frame methods (rigid-frame structure with rigid connections) by making the building frame and parts slimmer. Also, study of making longer spans and larger spaces and medium to tall buildings in over-track spaces may be required in the future with an eye to increased amenity and safety of station spaces. Development
of structure methods using damage control mechanisms is considered to be an effective measure in that. Furthermore, there are many challenging themes such as lightweight and high-performance new materials to replace conventional steel column and beams materials as well as new jointing methods for columns and beams. So, we plan to proceed while taking into account resources and priorities.

2) R&D contributing to promotion of infrastructure building and railway network enhancement projects to raise the value of conventional lines

Technical development is in demand to overcome various technical issues so projects can proceed smoothly. We are currently working on technical development themes such as the following in conjunction with departments carrying out construction. (1) Development of design and construction methods for reinforced concrete structure columns whereby construction can be carried out even in narrow spaces by arranging reinforcement bars more densely that with conventional construction methods, (2) Development to simplify workability of column-beam jointed structures in steel/concrete composite rigid-frame viaducts and artificial foundations, (3) Development of performance evaluation for advisability of use of new railway-use construction girders (construction girders temporarily set during under-track open cut construction work in cases such as station improvement) that do not need extra processing (or just minimum reinforcement) using general-use H shaped steel widely in circulation at construction sites as general use items and lease items, and for spec proposals if reinforcement is deemed necessary. Additionally, we plan to go forward with technical development for issue solving that contributes to promotion of individual projects.

3) Lessening environmental impact

(4) Lessening environmental impact (Fig. 10)

Prediction of and countermeasures against noise along Shinkansen tracks was covered in a past issue of the JR East Technical Review, so we will go over R&D for those issues concerning conventional lines here. Measures required at times such as when setting up new lines and conducting large-scale improvement work are covered in “Guidelines on Anti-Noise Measures for New Construction or Major Renovation of Conventional Railways” (1995, Ministry of the Environment). Points to note in construction plans regarding noise prediction are (1) Noise prediction and evaluation is at a distance of 12.5 m from the center of the track on the side of adjacent structures and 1.2 m above ground; and (2) Sound prediction methods are exemplified based on the outcome of research from the 1980s to 1990s, and those have become the standard methods when making predictions.

We are going forward with R&D for overcoming the following issues to contribute to streamlined construction plan taking into account the environment along the line such as in project promotion and measures for existing structures.

(1) Noise prediction in high spaces (spaces higher than the prediction/evaluation point 1.2 m higher from ground) with the previous prediction formula being estimated as larger than actual values has been shown from actual measurement results, so unreasonable countermeasure construction can be assumed to be proposed. From that, we are proceeding with research on improving and raising the accuracy of high-space prediction methods, taking into account previous research.

(2) Development to improve numerical analysis methods (finite difference method, etc.) that improve the noise diffusion model incorporating physical rules is need in addition to (1) to take
into account localized facilities along tracks such as for the effects of reflection, shielding, and other phenomena of nearby structures and detailed conditions of specific nearby structures. We thus plan to proceed with research on that.

(3) Conventionally, noise prediction for conventional lines has been at the many concrete viaducts in projects such as continuous level crossings. However, sound radiations characteristics in steel bridges where structural sound from trains passing stands out more than for concrete structures have not been ascertained, so a prediction method is not in place. In the future, spot noise prediction and countermeasures construction are assumed to be necessary for countermeasures to existing bridges and when steel bridges are selected due to their advantage in situations such as quick construction. And we plan to conduct basic investigative research on those.

(4) Effective noise reduction construction is in demand to reduce construction expenses when conducting countermeasure construction based on results of predictions. Currently, we are working on basic R&D such as reducing noise around the sound source. But we are also looking at joint research with related manufacturers in the future such as on wind pressure reducing sound insulation which reduces train draft pressure where the load borne by structures such as viaducts does not become large.

2) Environmental burden reduction in construction systems
Reduction of environmental burden in construction systems, 3R (reduce, reuse, recycle) technology and building technology for long-lasting railways will be needed in planning facilities investment for enhancing the station and rail transport network in the medium and long term. In that case, design, construction and assembly methods for LCC and reducing the environmental burden for new structures are assumed to become necessary along with reducing the environmental burden in demolition work when existing structures and railway facilities need to be demolished or rebuilt.

The following are examples of JR East R&D in environmentally compatible demolition methods carried out in recent years. We researched and developed a roadbed and grout-packed bed crushing method using static crushing material (concrete crushing method using expansion pressure generated over time when boring and filling concrete frames with cement expanding material, an internal expansion crushing method) to control noise and vibration when carrying out construction to convert low maintenance track sections with consolidated sleepers and ballast into ballasted track (construction of underpasses under tracks, construction girder building, etc.). We verified that about double the work of conventional methods (crushing by breakers and other devices) could be done daily by modifying the number and layout of bore holes, and later that has been used in construction and other work where noise and vibration reduction is required.

The service life of structures is generally set to be long-term, so design that takes into account renovation and reuse of frames is not done at time of construction. Therefore, existing structures and buildings are completely demolished by crushing and breaker methods in a scrap and build process in many cases. Up to now, technical interest by the structure owner in demolition work has not been very high, and work was dependent on specialized companies and the builder, so there has not been much technical innovation in this field. However, the manifestation of projects where demolition work for existing structures has a major position in project cost, progression, and other aspects can be imagined. So, with an eye on raised interest by the construction market in the possibilities of new, environmentally compatible demolition methods, we have to think of the possibilities of actions as the structure owner.

Conclusion
JR East executive officer Tadayoshi Ishibashi’s introductory special feature article mentions that R&D on design, construction, renovation, reinforcement, and other work required to promote many civil engineering and architectural projects in GV2020 needs to be carried out smoothly and effectively into the future. As an organization expected to have a clear mission of promoting R&D that contributes to those issues such as railway infrastructure, we plan to enhance cooperation with those promoting and executing projects, heighten our relationships with universities and construction-related companies, and heighten core technologies (abilities in areas such as design, structural planning, construction planning, analysis, cost calculation) as in-house engineers. Through that, we will plan to promote strong technical support from the aspect of R&D centering on human resources that will shoulder the technical burden of the next generation.

Reference: