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Disruptive Technologies in Railway, Hydraulic, and Architectural Engineering

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Abstract: Every technological and energy revolution in history has been accompanied with the emergence of disruptive technologies. Therefore, it is of tremendous significance to study disruptive technologies for the future development of various fields. This study analyzes the developmental directions and trends of railway, hydraulic, and architectural engineering. The results show that the developmental direction of railway engineering is along intelligent and high-speed development; hydraulic engineering conforms to nature and human–nature integration; and architectural engineering is developing to be precise, professional, mechanized, informationized, assembled, and eco-friendly. This paper summarizes the disruptive technologies in these three fields on the above basis. The disruptive technologies in the railway field include intelligent high-speed and low-vacuum pipeline magnetic levitation (maglev) railways. Those in the hydraulic field include the construction technology for basins having rich natural functions and the multi-objective joint dispatching technology for water resources and hydropower projects. Finally, the possible disruptive technologies in the field of architecture include the intelligent building technology based on building information modeling (BIM), industrial building technology, three-dimensional printing technology, and green building technology. Finally, this study proposes some suggestions to provide a reference for the research and development in railway, hydraulic, and architectural engineering.

Keywords: railway engineering; hydraulic engineering; architectural engineering; disruptive technology

1 Introduction

Disruptive technologies, also known as destructive, revolutionary, or transformative technologies, currently have no uniform definition. Depending on its technical attributes, a disruptive technology can be an innovative technology based on a new concept or principle, an application technology that supports equipment innovation, or a new technology generated by the cross-integration of multiple technologies [1–3].

Railway, hydraulic, and architectural engineering are traditional industries belonging to the category of application-oriented technologies. Throughout their developmental history, these fields have demonstrated themselves as strongly unitary, and the rates of the development of their corresponding engineering technologies have also been extremely low. However, with the accumulation of material wealth and progress of society, there is a constantly increasing demand for increased functionality, cost efficiency, and environmental friendliness in engineering. In general, railway, hydraulic, and architectural engineering technologies are characterized by a wide coverage, a strong professionalism, close technical connections, and low levels of automation.

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Disruptive technologies can interrupt the original mode and change the original relations of production. An engineering technology frequently involves a set of techniques instead of a single technology, and various technological collaborations are formed to complete the engineering tasks. Therefore, a certain mode of production is the result of the relation between the main body of the technology—the technical personnel—and production requirements. The emergence of a disruptive technology in engineering is caused by the transformation, subversion, or reorganization of one or several technologies. Specifically, a disruptive technology is a "resultant" of multiple technologies or an overall technology and is reflected externally as an interruption of the original mode of production. In addition, disruptive technologies should also have the ability to considerably improve the production efficiency.

2 Analysis of development trends in railway, hydraulic, and architectural engineering

2.1 Development direction of railway engineering

2.1.1 Development of intelligentization

Railways act as the backbone of integrated traffic and transport systems and play a key role in the economic and social development of China.

At present, a new round of scientific and technological innovation and industrial transformation is occurring following changes in unprecedented speed, coverage, depth, and impact. As an innovative technology that leads the future, the rapidly changing intelligent technology has injected a new vitality into the development of the railway industry. Some countries with advanced railway technologies have taken the initiative to capture this wave of new technology development, actively promoting interdisciplinary integration and accelerating strategies of railway digitalization and intelligentization. Germany has promoted Railway Development Plan 4.0, France has launched the "Digital Railway" project, and Japan has implemented an R&D program for the intelligent railway transport system, CyberRail [4,5].

By the end of 2017, the railway operating mileage of China reached 127,000 km, of which the high-speed railway operating mileage was 25,000 km, accounting for two-thirds of the total high-speed railway mileage of the world. According to the 13th Five-Year Plan for the Development of a Modern Integrated Transport System, the high-speed railway operating mileage in China will exceed 30,000 km by 2020 and a high-speed railway network with a reasonable layout, wide coverage, and complete functionality will be largely established. The development of a high-speed railway closely aligns with the major national policies and development strategies of China, including the Belt and Road Initiative and strategy of reinforcing the strength of China in transportation. In view of the new phase of scientific and technological revolution, the high-speed railway industry is replete with major technological innovation requirements and development opportunities. The key tasks that require urgent fulfillment for the current railway industry are to further improve the level of intelligence for high-speed railways and lead the global development of high-speed railways.

2.1.2 Developments leading to higher operating speeds

After years of combined debugging and commissioning, comprehensive testing, and operational runs with passengers, the design, construction, testing, operation, and maintenance technologies for the high-speed railway infrastructure of China have been validated for a speed of 350 km/h. This has led to the establishment of a complete technical system for the high-speed railway infrastructure corresponding to speeds of 350 km/h and below.

The railway industry of China has typically implemented a people-oriented concept and been committed to continually improve passenger comfort. In real-life scenarios, satisfactory passenger comfort can be maintained for a train travel time of 4 h or less. However, once the train travel time exceeds 6 h, the comfort level is reduced and people tend to prefer comparatively faster modes of transportation. China has a large land area, and consequently, long transportation distances. Therefore, it is necessary to develop a new transportation system with a relatively higher speed and energy efficiency.

Traditional wheel–rail transit is constrained by problems such as air resistance, wheel–rail adhesion, meandering instability, running noise, and pantograph–catenary speed limits. Moreover, the energy consumption and mechanical friction wear increase with speed. The highest economic and technical speed of a wheel–rail high-speed railway is approximately 400 km/h. At present, the economic speed of a cruise flight in aviation is 800–1000 km/h, indicating the speed gap between the two modes that must be overcome.

To achieve a higher economic speed than the current one, it is necessary to improve the traditional wheel–rail mode. Establishing a low-vacuum operating environment to reduce the air resistance and noise based on a suspension technology that can reduce the friction and vibration of rails will be an important development direction for a future railway technology delivering higher speeds.

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2.2 Development direction of hydraulic engineering

2.2.1 Development direction of water management

The current era is experiencing drastic climate change owing to the strong influence of human activities. Concerning water management in a changing environment, the primary demands are to construct a healthy natural–social water cycle system in a basin and manage water resources such that the ecological and socio-economic functions are maximized without causing disasters. The core concept is to regulate the social water cycle [6], which includes four main basic requirements: the social water cycle should not impair the objective laws of the natural water cycle; the social water cycle should not alter the ecological processes for natural water; the water ecosystem should evolve following natural laws, and the ecological service function of water should not be impeded; the social water cycle processes should not cause an enrichment of pollutants in the water bodies and not change the function of the water bodies; and the social water cycle processes should not affect the water and sediment processes, and the sediment should "go where it should go."

Therefore, integrated water management aims to comprehensively improve the integrated regulation ability of a basin based on the natural multi-process evolution mechanisms and laws of the water cycle in the basin. The objectives are to completely utilize the natural regulation ability of a basin, improve its overall regulation performance, and effectively respond to the "extreme" situations of the water cycle process. Effective water management must also improve the comprehensive service functions of river basins, conserve the functions of the life bodies in multi-ecological elements, and achieve coordination between nature and society. Owing to multiple interweaving water problems, the processes of water circulation, ecology, chemistry, and sedimentation should be comprehensively regulated to establish a coordinated basin with rich natural functions.

2.2.2 Development direction of hydraulic engineering management

With the intensification of the impact of human activities on the water circulation in a basin, the water resource system has been transformed from a simple hydrological system into a complex system consisting of the basic functions of the society, economy, water cycle, and ecology. The internal factors of the system are mutually constrained, promoted, and influenced to form an internal operational mechanism for a complex water resource system. This internal mechanism leads to a contradiction between the development of the human society and water resource system under the existing technical conditions, gradually forming a vicious circle. The rapid development of the society and growth of the economy continually impose increasing demands on the development and utilization of the water resource system, and unreasonable development and utilization leads to the emergence of a water crisis and deterioration of the ecological environment. Contrastingly, the shortage in water resources and consequent destruction of the water ecology and environments restrict economic and social development. Overcoming the difference between the social economy and water resource system to optimally balance the development and progress of the human society while retaining the health of the natural environment is a problem. The key is to effectively regulate the water resource system. Multi-objective dispatching of a group of hydraulic engineering projects provides a valuable approach for this purpose. This can effectively overcome the contradictions in the water use in the society, energy, and ecological systems and maximize the utilization efficiency of the water resources, thereby maximizing the comprehensive economic–social–ecological benefits [7].

2.3 Development direction of architectural engineering

Architectural engineering includes three stages: engineering planning, design, and construction. The development of an architectural technology exhibits six developmental trends: lean construction, professionalism, mechanization, informatization, prefabrication, and greening [8].

(1) Lean construction

Incorporating lean construction can promote the most reasonable utilization of the suitable resources, increase the profits of construction companies, and improve the performances of organizations. By implementing lean construction, the production efficiency of an organization can be improved, construction costs can be reduced, and quality of the projects can be enhanced.

(2) Professionalism

It is of considerable significance to promote the professional development of construction practitioners based on the current requirements of the construction industry and need of the country for the green sustainable development of the construction industry. Such development can relax the labor force, ease the labor intensity, and achieve efficient utilization of the human resources. Concurrently, the optimization from dual channels, i.e., engineering management and implementation, can avoid unnecessary resource consumption and reduce environmental pollution. In addition, professionalism can also provide reliably ensure improvements in the safety as well as speed and quality of construction projects.

(3) Mechanization

In modern construction, the demand for machinery and equipment is rising, and the degree of mechanization is also constantly increasing. In future construction, engineering machinery will gradually replace human labor and occupy the main position. The advantages of a mechanized construction include improvements in the efficiency of building constructions, high-quality projects, and reduction in the production costs.

(4) Informatization

In the construction domain, informatization is a product of combining the construction technology with the emerging information technology. This is an inevitable result of the development of science and technology, social economy, and information communication. In the modern information society, buildings are not simply protection against natural elements; they also represent an intelligent combination of people, information, and the work environment. The complete utilization of the information technology will arise as an indicator of future architecture.

(5) Prefabrication

Prefabricated construction involves manufacturing industrial products (components, accessories, and parts) in a factory using industrial methods. Based on the various requirements at the construction site, these products are subsequently assembled and installed using the engineering technologies of mechanization and informatization to build specific building products. Prefabricated construction should realize the standardization of architectural designing; industrialization of component manufacturing; prefabrication of temporary facilities and structural components; integration of accessories; integration of equipment and pipelines; mechanization of on-site construction; matching of component supplies; informatization of engineering management; professionalization of operators; and diversity in architectural forms. In contrast with the traditional cast-in-place mode, prefabricated construction can shift numerous high-intensity operations from the construction site to a workstation in an artificially controllable work environment to enable modern production. This can reduce the on-site workload, and thus, also considerably reduce the dust, noise, and waste discharge; improve the working conditions; reduce the labor intensity; promote environmental friendliness; reduce the pollution; improve the green level; promote industrial chain integration; diversify buildings; reduce the potential construction safety issues; and ensure the building quality. Prefabricated construction involves manufacturing building products by replacing the traditional manual production mode with a modern industrialized large-scale production mode. Thus, prefabricated construction is an important direction for the development of the construction industry.

(6) Greening

In general, the trend of construction development is toward green construction. Green construction is an engineering activity that focuses on the entire life cycle of a building and implements the concept of sustainable development under the premise of ensuring high quality and safety. By scientific management and technological advancements, green construction can maximally conserve the resources, protect the environment, and produce green building products. The basic concept of green construction pertains to resource conservation, environmental friendliness, process safety, and quality assurance.

3 Potential disruptive technologies that deserve consideration

3.1 Railway engineering

3.1.1 Intelligent high-speed railway technology

An intelligent high-speed railway technology represents an unconditional subversion of a high-speed railway technology. Based on the original high-speed railway mode, modern technologies, such as building information modeling (BIM), cloud computing, the Internet of Things, big data, artificial intelligence, and next-generation communication, are widely applied. All the mobile, fixed, space, time, and workforce resources of high-speed railways are efficiently utilized by comprehensive perception, ubiquitous interconnection, integrated processing, and scientific decision-making pertaining to mobile equipment, fixed infrastructures, and related internal and external environmental information concerning high-speed railways. This encompasses aspects such as smart trains, smart passenger transportation, smart infrastructure, smart dispatching, smart engineering construction, smart management, smart security monitoring, and smart maintenance and repair. This technology is applied to the overall intelligence of the entire business process, complete value chain, entire life cycle, and whole ecosystem of high-speed railways. This paradigmatically subverts the original high-speed railway mode in terms of the construction, electric multiple units, train control, traction power supply, operation management, and risk prevention and control.

Currently, the railway department is conducting a transformation to intelligent construction for the Beijing–Zhangjiakou and Beijing–Xiong’an railways. It is expected that in 2020, the paradigms of smart Beijing–Zhangjiakou and smart Beijing–Xiong’an railways will be completed, and the station service function will be optimized to provide more convenient smart services to the passengers. Automatic driving will be realized by smart trains, and smart train dispatching and early prevention

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and warning systems will be adopted to comprehensively improve the railway safety level and operations management. By 2035, green high-speed EMUs with storable energy, intelligent operation of trains under independent and unmanned conditions, and high intelligence over the whole process and entire life cycle of high-speed railways will be realized via intelligent construction. Moreover, an intelligent high-speed railway network will be established in the initial stages.

3.1.2 Low-vacuum pipeline maglev railway technology

A low-vacuum pipeline maglev can be considered as an independent subversion of high-speed railways. This technology may subvert the established wheel–rail concept and relatively mature high-speed maglev concept, and lead to the construction of a completely different technical system in terms of system integration, mobile equipment, infrastructure, operation and control communication, operation services, and safety.

In theory, the vacuum pipeline technology can allow a train to operate in a vacuum environment, i.e., without air resistance, which can considerably increase the speed of a maglev train. However, because a high-speed low-vacuum pipeline maglev system is new and challenging, several issues exist: multiple problems pertaining to the implementation of the vacuum piping technology remain to be solved, and relevant safety issues must be critically considered. Moreover, the promotion of this mode of transportation for large passenger volumes may be difficult. This is because the engineering requirements are demanding, maintenance of the vacuum pipeline remains to be verified, and there exist many challenges in terms of comfort and economics. Under this premise, the current phase of this technology is mainly dominated by the market, and the technology remains in the developmental stage of incubation.

Therefore, prospective research should be conducted in response to the above problems and uncertainties, and a planning and feasibility study of a pilot line construction should be performed to provide an empirical basis for the subsequent operations.

3.2 Hydraulic engineering

3.2.1 Technology for basin construction with coordination of rich natural functions

The objectives of basin construction with the coordination of rich natural functions involve completely exploiting the regulation effect of the natural system of water circulation. This is based on the multiple water circulation processes of the river basin, standardization of the human activities for soil and water resource development, and reduction in the disturbances to natural water circulation. This technology also aims to systematically establish gray infrastructure (reservoirs, embankments, canals, pumping stations, and wells), green infrastructure (forests, grasslands, and wetlands), and red infrastructure (smart water networks and services). In addition, its goals are to construct brown (ground water) and blue reservoirs (aquifers and other underground spaces) and integrate the progress of modern information technology to realize the joint regulation of surface-soil–underground multi-processes and water quantity–water quality–sand–water ecology. This technology also neutralizes the extreme values to the largest extent and systematically solves the water problems in the basin. The overall goal of such basin construction is to perform coordination and control considering eight aspects: water resources, water safety, water environment, water ecology, water management, water landscape, water culture, and water economy, by the systematic establishment of a five-color infrastructure. This lead to the development of a healthy nature–society water circulation system.

China took a global lead in proposing the concept of coordinating basins with rich natural functions and has achieved progress in its theoretical framework, top-level design, and key technologies [6]. Presently, pilot basin projects are being conducted in typical small basins in the Huaihe river basin, and the number of these pilot basins will be gradually increased. The concept is expected to be implemented in major river basins nationwide after 2030, and they will be completely established with the coordination of rich natural functions in 2050.

The construction of coordinating basins with rich natural functions has three characteristics and advantages:

(1) The technique can completely integrate the theory of the life body of multi-ecological elements, thereby enriching the connotations of water management. It wholly considers the regulation abilities of the natural geographical entities to coordinate the construction of green, gray, brown, blue, and red infrastructures and reform the water management mode.

(2) The technique focuses on system governance and functional improvement, different from the construction of ecological and clean basins. The latter focuses on changes in the ecological and water quality conditions, which does not involve the complete consideration of the multiple processes of water circulation in the governance targets. It is difficult to adapt to the comprehensive water safety requirements in response to a changing environment, and a long-term mechanism is lacking. The construction of coordinating basins with rich natural functions not only focuses on water management and storage but also helps to clean the environment and conserve the ecosystem.

(3) The technique can completely absorb the essence of the construction of sponge farmlands and cities and realize multidimensional stereoscopic storage. Compared with that of a basin, the construction of a sponge city is regulated only on

the point-scale and that of a sponge farmland only on the patch-scale, which involves the regulation of a single process. However, coordinating basins with rich natural functions considers the basin as the basic unit to implement a multidimensional stereoscopic regulation. The construction of coordinating basins with rich natural functions is not only a requirement for comprehensive river basin management but also an inevitable trend of the development of human civilization. The economic benefits are notable, with immense social significance.

3.2.2 Multi-objective joint dispatching technology for a group of water resources and hydropower projects

The guiding ideology of multi-objective joint dispatching for a group of water resources and hydropower projects includes the harmonious coexistence of man and nature and maintenance and conservation of the ecological integrity of the rivers and lakes. The core of this dispatching involves integrating the regulation of the water–ecology–energy coupling system with the water system. In addition, intelligent technologies, such as big data and cloud computing, are integrated to achieve multi-objective joint dispatching of a large complex system. This can unify and coordinate the dispatching of reservoirs and related facilities with hydrological and hydraulic connections, thereby achieving more benefits, which are difficult to achieve via separate dispatching.

With the continuous advancement of hydrometeorological forecasting, computer application technology, and complex systems control science, some new theories and technologies suitable for reservoir group system dispatching have been proposed. They have demonstrated the following broad developments and application prospects: (1) In terms of real-time forecasting and scheduling, these technologies can help to quantify the uncertainties of meteorological and hydrological forecasting under a changing environment and assist in the decision-making of uncertain rolling dispatching for coupled forecasting; (2) in ecologically oriented dispatching, the utilization of these technologies can establish an assessment mechanism for the ecological health of a river and an ecology-oriented multi-objective integrated scheduling mode for a group of reservoirs; and (3) the adoption of these technologies in multi-energy complementary dispatching can help to combine systems theory, cybernetics, and other theoretical methods to analyze the mutual feeding relationship between the reservoir group system and new energy system. Moreover, these can assist in establishing a joint scheduling mechanism for water–energy integration.

Regarding the main driving force of development, although the construction of hydraulic and hydropower projects is guided by the government, their management and operation are eventually market-oriented. Therefore, multi-objective joint dispatching of water resources and hydropower projects belongs to the combined domain of the government and market. Based on the degree of subversion, multi-objective joint dispatching for a group of water resources and hydropower projects involves not only the entire hydraulic industry but also the fields of ecology, environmental protection, meteorology, and energy, which pertain to the coupling of water–ecology–energy systems. This key technology realizes the harmonious coexistence of humans with nature, embodying the thoughts of the Chinese president, Xi Jinping, for a new era. Therefore, it can be seen as an epochal subversion. Regarding the development stage, multi-objective joint dispatching for a group of water resources and hydropower projects has passed the germination stage and is currently in the breakthrough stage, with typical case exploration being performed and key technical breakthroughs being achieved. To evaluate key breakthrough points, multi-objective joint dispatching for a group of water resources and hydropower projects involves multiple intersecting disciplines including hydrology, meteorology, ecology, flood control, power generation, water supply, shipping, and electricity. Various technologies must be comprehensively applied, and thus, this represents a form of multidisciplinary technology. Overall, multi-objective joint dispatching for a group of water resources and hydropower projects can not only maximize the utilization efficiency of water resources and achieve economic benefits for them but also coordinate the water use contradictions of the social, energy, ecological, and other systems. This demonstrates the notable economic benefits and immense significance for the society.

3.3 Architectural engineering

In future architectural engineering, disruptive technologies may adopt the following directions: BIM-based intelligent construction technology, three-dimensional (3D) printing technology, industrialized construction technology, and green construction technology.

3.3.1 BIM-based intelligent construction

The BIM technology is the basic technology for achieving digital modeling of future construction projects. It involves the complete management of the planning, design, construction, and operation of projects using digital models. BIM can effectively realize the establishment of resource plans; control the quality, safety, and funding risks; reduce the energy consumption and financial costs; and improve the efficiency at all stages of the project life cycle. This can considerably enhance the informatization level in the operation and maintenance management of engineering construction and advance the

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global soft power of Chinese technology. In the future, BIM may arise as another revolution in construction engineering with disruptive significance [9,10].

The main driving force of the development of a BIM-based intelligent construction technology is the market, and this technology is in the breakthrough stage. A BIM-based intelligent construction technology can integrate the design, construction, operation, and maintenance of a project to improve the construction and management efficiency, eventually lead to a reduction in the materials and labor and increased economic value. Intelligent construction methods can considerably reduce the labor, improve the working environment and sense of well-being for the construction workers, and achieve a notable social value.

3.3.2 Industrialized construction

The development path of a construction method is illustrated in Figure 1. With the maturity and development of excavators, concrete pump trucks, tower cranes, and other machinery, mechanized construction has gradually replaced conventional manpower-dominated operations. With the advancement in the production methods of construction materials and components in factories and the development of prefabricated construction methods and green construction, in the future, industrialized construction may replace existing wet-operation-based construction methods and become a disruptive technology.

With the development and progress of the construction technology, the industrialized construction mode, which can improve the construction quality, reduce environmental pollution, ensure the safety and health of the workers, and enhance the construction efficiency, will become the convention in the future. In the industrialized construction mode, standardized prefabricated components can be produced in a factory and subsequently assembled on-site by professional workers, which is in line with the concept of green low-carbon and sustainable development. For the existing wet-operation-oriented construction methods, industrialized construction will represent the direction of future development and may become a disruptive technology [11,12].

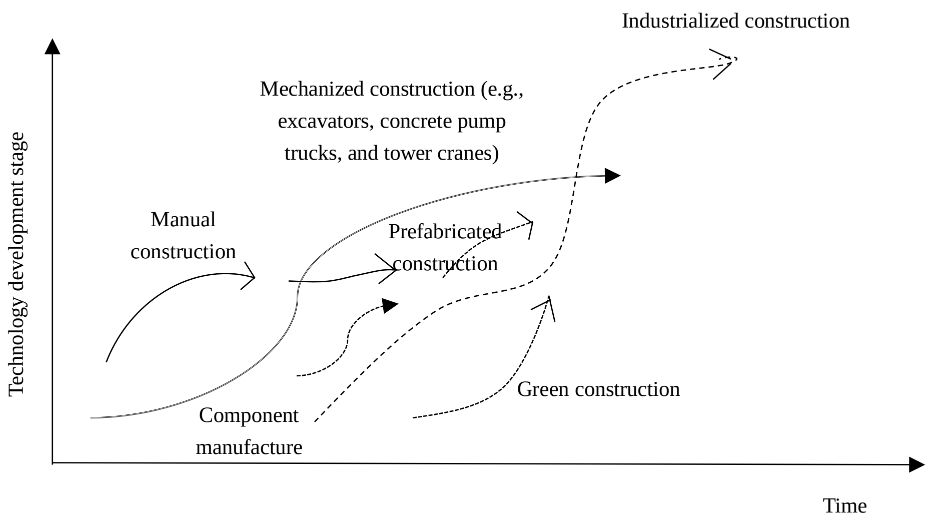

Fig. 1. Development path of the construction methods.

The main driving force in the development of the industrialized construction technology is the combination of the government and market, and this technology is in the breakthrough stage in the development process. The industrialized construction method involves the construction of buildings based on the method of large-scale industrialized production. This approach can improve the construction efficiency and product performance and lead to a good economic value. Industrialized construction methods can improve the working environment and sense of well-being for construction workers, thereby demonstrating a notable social value.

3.3.3 Three-dimensional printing construction

The 3D printing construction technology is entirely mechanized and can completely subvert the traditional construction methods. A 3D printing construction can enable the construction of more complex buildings and represents an important development direction for the construction industry. However, the 3D printing construction technology in China is currently in its infant stage. The corresponding equipment production and construction processes have rarely been performed on a large scale, and no systematic conditions have been formulated for the advancement of the specific processes and methods. However, 3D printing construction employs information technology and mechanization as the core technical approaches, and thus, it can shorten the construction period and reduce the labor, thereby considerably reducing the labor dependence. Moreover, this approach can considerably reduce the labor intensity of the construction workers, improve the working environments, and increase the work productivity. Therefore, it may become a disruptive technology in the future [13–15].

The main driving force behind the development of the 3D printing technology is the market, and this technology is in a nascent stage. The 3D printing technology allows the construction of specific-shaped buildings and parts more conveniently and economically. Furthermore, it enriches the diversity of buildings and achieves a good economic value. The 3D printing technology can improve the degree of mechanization and reduce the labor costs, demonstrating a notable social value.

3.3.4 Green construction

Green construction refers to the complete process of engineering construction, including the three stages of green planning, green design, and green construction for an engineering project. However, green construction is not a simple superposition of these three stages but rather an organic integration. Green construction can encourage all the stakeholders to participate in the overall project, including the project planning, design, material selection, building equipment selection, and construction process, based on the overall perspective of the project, which can facilitate the realization of green objectives and lead to comprehensive benefits. Thus, this may become a disruptive technology [8,16]. The main driving force for the development of the green construction technology is the combination of the government and market, and this technology is in the breakthrough stage.

4 Conclusion and suggestions

This study investigated the connotations of disruptive technologies in railway, hydraulic, and architectural engineering; analyzed the developmental trends of the disruptive technologies; and described the technical development directions of the disruptive innovations in the field of engineering. Based on the obtained research results, the following suggestions are proposed for the development of disruptive technologies in the railway, hydraulic, and architectural engineering sectors:

(1) Actively promote research in and the application of intelligent construction and operation and maintenance technologies for engineering projects

BIM-based engineering design, construction, and management should be actively studied and promoted to deepen and advance the development of the engineering prefabrication technology and 3D printing technology for components with a high added value and realize industrialized production integrated with the design, manufacture, and assembly processes. The automation and informatization level of engineering construction should be vigorously improved. Robot construction technology should be studied and developed considering complex working conditions. Low-energy consumption monitoring sensor networks and prognostics and health management technologies based on the Internet of Things should be developed. A deep integration of traditional engineering with modern technologies should be comprehensively promoted to establish a people-oriented green-engineering construction model that realizes high safety, high quality, low energy consumption, and environmental friendliness. This can lead to a new mode of construction engineering based on the BIM technology, which is supported by the modern information and artificial intelligence technologies and covers the entire lifecycle.

(2) Promote research in and the application of key technologies for smart railways and low-vacuum pipeline maglev railways

Key technologies and applications, such as smart railway construction; smart facilities and equipment; smart dispatching, operation, and maintenance; and smart security, should be studied. This will promote the intelligent development of the Chinese railways, provide a better experience to passengers, lead to economic and social development, and powerfully support the national strategy of increasing the strength of China in transportation.

Combined with the developmental directions of urban and metropolitan underground spaces and existence of numerous tunnels in the high-speed railway system of China, an underground closed pipeline should be constructed and integrated with the technical system of maglev high-speed railways to form a low-vacuum pipeline maglev railway system with an operating speed of 600 km/h or higher. This will fill the gap between aviation and wheel–rail high-speed railways, realizing the strategic necessity for maintaining the international leading position of China in the high-speed railway technology.

(3) Accelerate the construction of coordinating basins with rich natural functions

By constructing coordinating basins with rich natural functions, the comprehensive service functions of the basins will be improved to realize the life body of the multi-ecological elements and a harmonious coexistence between humans and nature, which will provide a new mode of water management in the new era. By the optimal distribution of the infrastructure, a

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coordination between the multiple water cycle processes, slope–channel process, surface–soil–underground process, normal process, and extreme process should be realized. This will ensure that the water and sand flow to where they are required, resources are assigned to relevant areas, and land is occupied by the creatures that it should nurture.

(4) Actively explore water–wind–light multi-energy complementary basin joint dispatching

The coordinated development of water–wind–light integration should be in line with the natural laws of the existing resources for which the market demand is high. By the complementary operation and coordinated scheduling of wind power, photovoltaic energy, and hydropower, the hydropower regulation function can be completely utilized to compensate for photovoltaic and wind power generation, which can significantly reduce the randomness, volatility, and intermittent drawbacks of wind–light power generation. Water–wind–light multi-energy multi-dimensional development and dispatching will allow for the full utilization of the land, increase the amount of high-quality and clean power supply, and provide inexhaustible power for the healthy development of the national economy.

(5) Actively promote green construction

Conserving resources and protecting the environment are the bases for the sustainable development of the human society. Therefore, in the process of engineering construction in railway, hydraulic, and architectural engineering, the abovementioned concepts should be implemented and green construction should be practiced.

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