ARCHIVES OF TRANSPORT *ISSN (print):* *0866-9546*
Volume 38, Issue 2, 2016 ***e-ISSN (online):*** *2300-8830*
DOI: *10.5604/08669546.1218799*

COMPUTER-AIDED MODEL CONSTRUCTION AND DATABASE DESIGN OF RAILWAY YARD INFORMATION

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Abstract: *Railway yard is the basic composition unit of railways, therefore, the efficiency and quality of railway yard design have a crucial effect on the construction and operation of railways. Plane design is the basis and core of railway yard design, consequently, it is significant to research plane design of railway yard. In this study, through analysis and summary of the research status as well as integrated application of computer technology and railway yard plane design methods, we researched and developed railway yard plane design system based on AutoCAD platform. According to the characteristics of railway yard plane design, we constructed the information model based on which we established specialized database, with the information data organized and managed efficiently; moreover, we put forward methods of constructing geometric models of the plane equipment, meanwhile, we did a focused research on associated design of yard equipment and preliminarily realized linkage design of planar yards.*

Key words: *railway yard, information model, database, system development.*

1. Introduction

As the bond of the frontier and the back of stations, railway yard plays a key role (Peng et al., 2014). The efficiency and quality of railway yard design have a vital effect on the construction and operation of railways (Yuan et al., 2014), and the design quality directly affects railway engineering, operational indicators and transport capacity. As the basis and core of railway yard design (Zhu, 2008), plane design directly affects the follow-up profile design, cross-sectional design, 3D visual design and calculation of engineering quantity, therefore, it is of great significance to research on the theories of railway yard plane design (Yang, 2006). Since 1960s, a large number of scholars and R&D institutions have carried on thorough researches on the theories and methods of railway yard plane design, and developed a series of computer-aided design software (Liu et al., 2012). For example, Li et al. (2015) put forward practical railway yard design mode along with the requirements of target, function, overall structure, data flow and the key technology; Durmuş et al. (2010) researched on computer-aided railway yard design; Liang et al. (2013) carried out simulation system design of railway yard based on J2EE technology.

Overall, the software systems mentioned above improve the efficiency of railway yard design to some extent, however, some software are short of professional database and independent organization and management mechanism, with mass data completely under the management of AutoCAD platform; even if there is database, the simple and rough design makes it difficult to complete a mass of editing and modification; and most software neglect associated constraint design. In brief, with limited functions, the existing software fail to fundamentally solve the problems in digital design of railway yard, and software development is still in a relatively low level (Krishnapillai & Zeid, 2006; Zhou, 2013).

In this study, to begin with, we constructed scientific and reasonable railway yard information models, followed by the design of data models of equipment in railway yard plane; then, we established specialized database of railway yard plane, and researched on various associated design methods; furthermore, we set up behavioral models of railway yard plane design; with AutoCAD adopted as the development platform, we developed new railway yard plane design system which can greatly improve the efficiency, quality and level of railway yard design.

2. Overall design of the system

2.1. Overall goal of the system

The overall goal of developing railway yard plane design system is to achieve functional maturation, process clearness, accurate calculation, standard graphical representation, simple operation, and meet the requirements of digital plane design (in the phases of pre-feasibility study, preliminary design and construction documents design) of railway yard (of mixed passenger and freight railway and high speed railway). By establishing the plane scheme database and storing the plane design data information of railway yard, along with the application of spatial index technology, efficient organization and management of railway yard data can be achieved. With man-machine interactive design method adopted, railway yard plane scheme can be generated and modified. The design process and graphic output are mutually independent; once the design is completed, design result output can be implemented rapidly by means of graphs and forms.

2.2. Overall structure and function design of the system

According to the overall goal, the system is divided into four modules— project management, database, plane design and diagram output. There is business logic connection between project management, plane design and diagram output, and system can conduct unified management on the three modules through database. Overall structure of the system is shown in figure 1.

2.3. Operation and data process of the system

Operation and data process of the system is shown in figure 2. In the flow chart railway yard plane design data mainly include normal data, basic data, input data and result data (Roanes-Lozano et al., 2002; Thuraisingham, 2007).

2.4. Development tools of the system

This system adopts a variety of development tools, such as C++, ObjectARX and database, at the same time, AutoCAD is developed based on ObjectARX2012. As a fully object-oriented development tool of computer-aided design, ObjectARX allows developers to use object-oriented C++ language to customize entity objects for AutoCAD so as to meet practical needs. The entity objects are similar to the internal entity of AutoCAD and reflect the object-oriented design concept. In this study, on account of the moderate data size, and data relations in the railway yard plane design system were not very complex, we chose a small-scale database management system. The small-scale relational database management system (RDMS) Access is easy to operate, with full functions, friendly interface and simple configuration, in addition, it is completely compatible with Windows.

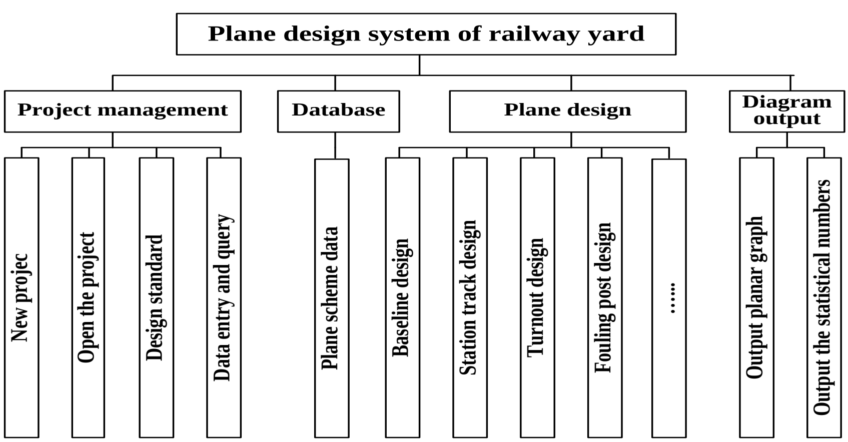

Fig. 1. Overall structure of the system

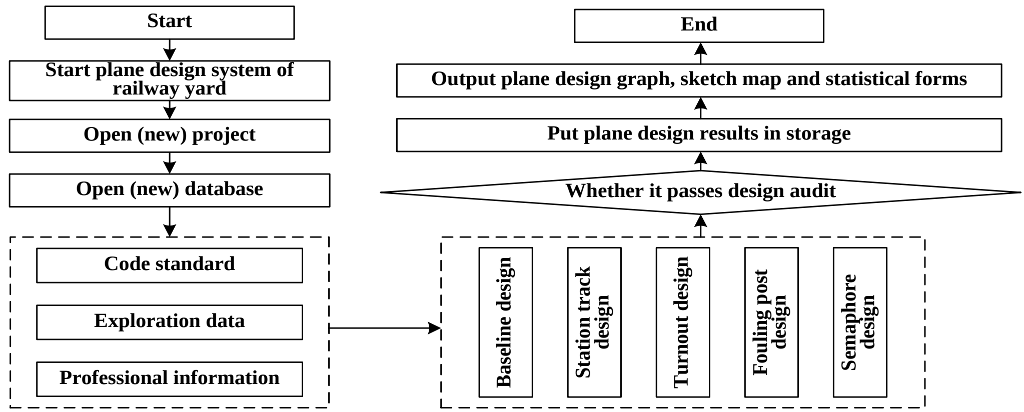

Fig. 2. Operation and data process of the system

3. Construction of railway yard information model and database design

3.1. Construction of railway yard information model

(1) *Geographical environment information*

Geographical environment information (including digital terrain, digital geology and digital environment) is an important part of railway yard information model. Digital environment information covers the information of farmland, river, buildings and nature reserves in station area. The information contributes to the coordination between railway yard plane design and the surrounding environment by avoiding unnecessary demolition and land acquisition and reducing project cost.

(2) *Information of railway yard equipment*

This paper gave systematic analysis and induction of various equipment in railway yard. The equipment can be divided into line equipment, turnout, signal equipment, passengers and freight equipment and other accessory equipment. It is necessary to describe the data model of each equipment accurately and express its behavioral model. The information of railway yard equipment is shown in table 1.

(3) *Information of railway structures*

Site selection and plan design of railway yard are usually completed on condition that the railway structures (route, bridge and tunnel) have been determined (Kardas-Cinal, 2014). This paper constructed the information model of railway structures (route, bridge and tunnel).

Table 1. Information of railway yard equipment

Railway yard equipment	Data model	Behavioral model
Line equipment	To describe the route's basic attributes, line element constitute, effective length of station track.	To introduce, create, edit and save route, also used for route connection and attribute matching.
Turnout	To describe the serial number, type, location and size of turnout.	To import, create, edit, move and save turnout.
Signal equipment	To describe the semaphore number, associated turnout and station track, coordinate position of fouling post.	To import, create, edit and save fouling post and semaphore and achieve automatic calculation of their coordinate positions.
Passengers and freight equipment	To describe the basic attributes, location, size and associated information of station platform, station building, over-bridge tunnel and warehouse.	To import, create, edit and save station platform, station building, over-bridge tunnel and warehouse.
Other accessory equipment	To describe the basic attributes, location, size and associated information of the road, drainage ditch, fence and etc.	To import, create, edit and save the road, drainage ditch, fence and etc.

Plane design of railway yard is based on the design data of route profession which provides route database file for yard profession; based on the file, railway yard profession creates planar baseline entity.
Plane design of railway yard also requires the information of bridge and tunnel; the given railway yard technology standards from users as well as the beginning and end of the bridge and tunnel can be offered as reference for yard profession so that the settings meet the requirements.

(4) Associated constraint information
There are plenty of associated constraints in the plane design of railway yard. In this study, based on the analysis and summary of associated constraints between various equipment in the railway yard plane, we constructed associated constraint information model so as to achieve effective organization and management of complex association and constraint relations. The association diagram of railway yard plane equipment is shown in figure 3.

3.2. Database design

(1) *Data structures*
In the data structures, the basic attributes (type, location and size) of railway yard plane equipment are described, moreover, associated information between the equipment is recorded to meet the requirements of associated constraint design. Therefore, data structures of railway yard plane equipment include basic attributes and associated attributes.
(2) *Database design*
In this system, the plane scheme is named as *.mdb file. The information of each plane equipment is saved in database in the form of table. Table structure is determined according to data structure so as to make it convenient for plane scheme and each equipment to implement rapid import and storage, which sets the foundation for result output. Turnout plane data (the basic attributes and associated attributes) are stored in turnout table, as shown in table 2.

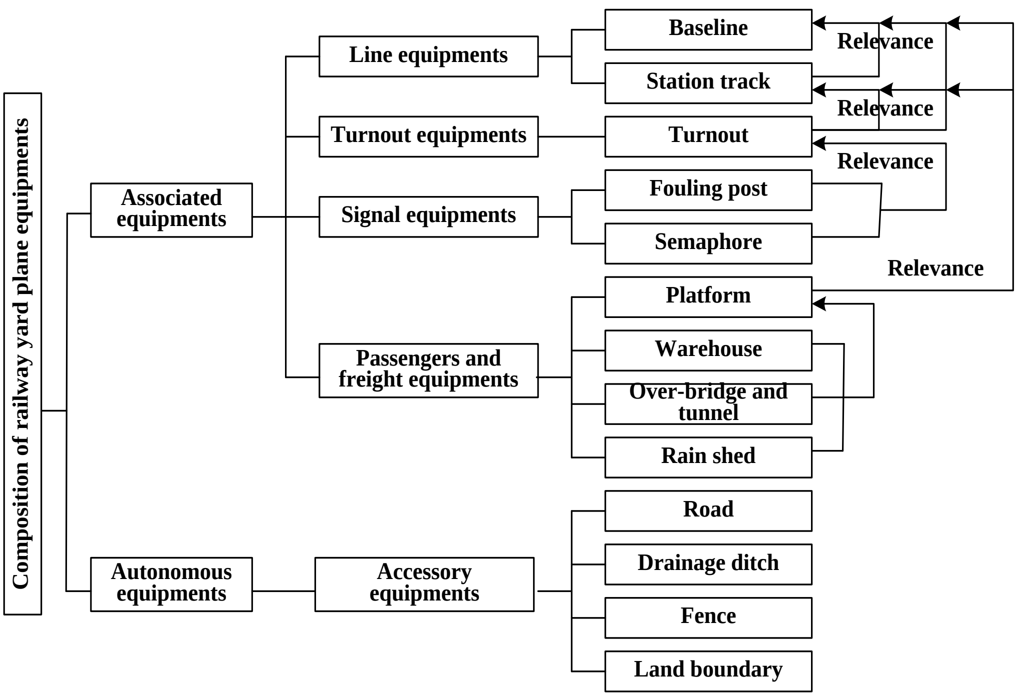

Fig. 3.The association diagram of railway yard equipment

Table 2. Table of turnouts

Field name	Data type	Field name	Data type
Serial number of turnout	Figure	Steel rail type	Text
Turnout number	Figure	Type of turnout tie	Text
Turnout type	Figure	Serial number of station track/ baseline	Text
Turn left or right	Figure	Serial number of the educt station track/ baseline	Text
Initial azimuth angle	Figure	Chart number	Text
Frog mileage	Figure	Tense of design	Text
Coordinate of frog N	Figure	Prefix of serial number	Text
Coordinate of frog E	Figure	/	/

4. Railway yard plane design

4.1. Route design

(1) *Line element geometry model*

During the plane design of railway yard route, geometry parameters of line elements include: the properties and size of line element; turn around; azimuth angle of line element initial tangent; mileage and coordinate of the starting point. Railway yard line is composed of several line elements. In order to describe the information of these line elements, we adopted two-dimension XYAiTay for encoding.

(2) *Baseline design*

As the foundation of railway yard plane design, baseline is generally absolute alignment, while station track is relative baseline alignment. Therefore, baseline design is the top priority. According to actual project requirements, baseline design is supposed to be able to import, create and add line elements along with the functions of editing, deleting and saving; it can generate baseline with centerline data; and it also has the functions of mileage and coordinate transformation.

(3) *Station track design*

Station track design is an important part of railway yard plane design and the foundation of subsequent design work. In view of the actual project requirements, we formulated detailed design methods (figure 4).

4.2. Turnout design

(1) *Geometry model of line elements*

The main line of lateral turnout is straight line, while the lateral line branches out to the left or right side of main line, in the form of left-lateral and right-lateral (Qing-Yuan, 2003). In practice, in order to meet design requirements, the center line of the two lines at turnout and the intersection denote turnout, which is a more simple and convenient drawing method (Gao et al., 2011). Based on the model above, we adopted one-dimensional array (XYArray) in program coding to describe the attributes of turnout.

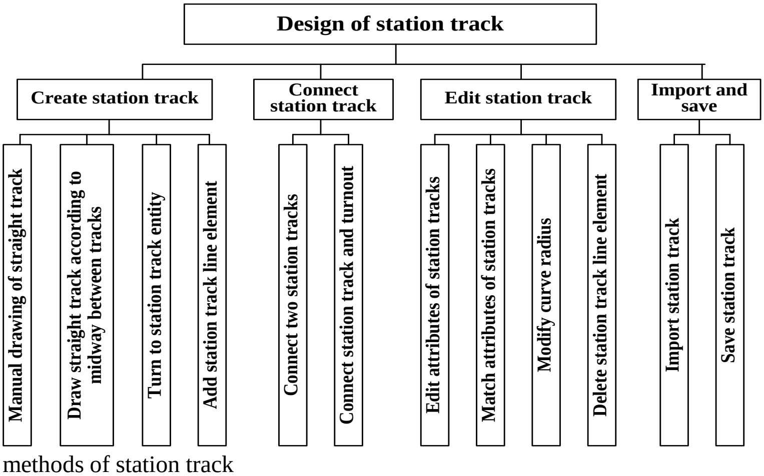

Fig. 4. Design methods of station track

(2) *Design content and implementation*
In this study, we aimed at the association of turnout and line equipment as well as the association of turnout and signal equipment. Turnout design is implemented through creating, editing and moving turnout.

(3) *Junction line design*
Junction line (including single junction line, shortened junction line and crossed junction line) refers to the equipment that leads rolling stock from a line into another. With turnout and station track involved, junction line has complex structure. In order to facilitate the editing and modification functions of junction line, the system turns it into user-defined entity, and integrates turnout and station track line elements.

4.3. Coordinates of fouling post and semaphore

Coordinate positions of fouling post and semaphore are affected by the following factors: turnout frog angle, geometry elements of the line connected with turnout, whether out-of-gauge goods train can go through (Gamon, 2015). According to these factors, we can form the path lines where fouling post or semaphore is set up along the line of turnout and derivative line, and intersection of the two path lines is the theoretical coordinate position. For example, the turnout (whose frog angle is α) connects line 1 and line 2, turnout center O is the origin, back tangent of line 1 is in the direction of axis X, thus the rectangular plane coordinate system is established, and then, the limit path lines of line 1 and line 2 are located. When the two dotted lines intersect, the intersection is obviously the theoretical position of fouling post or semaphore, and y values of the dotted lines are the same.

4.4. Design of passengers and freight equipment

(1) *Passenger traffic equipment*
The ground of passengers' station buildings should be on the same height (or on slightly different height) as basic platform. Passengers' platforms include basic platform and intermediate platform. In general, the length of passenger platform is 400 m to 500 m. As to the platforms designed for short distance or suburb passenger trains, the platform length (no less than 300 m) is determined according to the actual lengths of the trains, and the width of platform is no less than 6 m.

Crossing equipment (including flat corridor, over-bridge and tunnel) refer to the passageways between station buildings and platform or between platforms. This study focused on the design principles of over-bridge and tunnel.

(2) *Freight equipment*
Freight equipment in railway yard include freight yard, goods platform, merchandise warehouse, loading and unloading machines, handling machinery, offices and living rooms (Zhai et al., 2010).
Freight yard is not only a production workshop in station, but also the site for freight transport as well as the link between railway and local short-distance transportation. The layout patterns of freight yard include dead-end type, pass-type and hybrid-type.
Freight platforms include common platform and high platform. Common platforms are 0.5 m to 1.1 m higher than the rail level; the ones more than 1.1 m higher than the rail level are high platforms. Warehouses at intermediate stations are generally set up on the basic platforms, close to station buildings.

4.5. Calculation of the space between station lines

(1) *Cause of widened space between curved station lines*
When rolling stock is in curve section, the middle part of the rolling stock bulges inward by W_1, while both ends bulge outward by W_2.
Suppose the outer rail at curve section is super-elevated; bodywork tilts inward; the distance to the rail surface is H; bodywork tilts inward by W_3.

(2) *Widening requirements of the space between curved station lines*
Suppose the super-elevation value is h_W on outward curve and h_N on inward curve; according to the relative height difference of h_W and h_N, calculating formulas for widened space between curved station lines are:

- if $h_W \le h_N$ then $W = W_1 + W_2 = \dfrac{84500}{R}$ (mm)

- if $h_W > h_N > 0$ then
$$W = W_1 + W_2 + W_3 = \frac{84500}{R} + \frac{2}{3}h \text{ (mm)}$$

if $h_W>0$ and $h_N=0$ then

$$W=W_1+W_2+W_3=\frac{84500}{R}+\frac{4}{3}h\ (mm)$$

4.6. Calculation of station line length

Station line length includes total track length, railway length and effective track length. Total track length refers to the length between the stock rail joints at both ends. Railway length is obtained by subtracting the length of all turnouts from total track length. Control marks of effective track length include departure semaphore, fouling post, point of switch and bumper post. Effective track length is calculated separately according to ascending route and descending route. As shown in figure 5, on descending route, the effective length of track 1 starts from the departure semaphore to the fouling post on the other end; on ascending route, the effective length starts from the departure semaphore to the stock rail joint on the other end. As for track 2 and track 3, the effective length starts from departure semaphore in corresponding direction to the fouling post on the other end. In the figure, departure semaphore in each turnout is located on the left side (in departure direction); when there are fouling posts on both sides, the closer one is taken as the control marker.

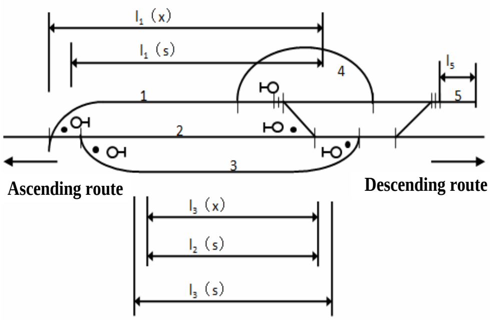

Fig. 5. Sketch map of effective track length

5. Conclusion

In this study, according to the characteristics of railway yard plane design, we constructed railway yard information model which involved information of geographical environment, railway yard equipment, railway structures and associated constraints; then, we summarized and analyzed the data models and behavioral models of the information; based on railway yard information model, professional database was set up with database management technologies which offered efficient organization and management of all kinds of information data; through efficient spatial index, rapid access to the required data and information output could be achieved; to some degree, establishment of database guaranteed associated constraint design, linkage design of graphics and data; moreover, we put forward the methods for building geometric models of railway yard plane equipment; through user-defined entity technology, we implemented the customization and modular encapsulation of the equipment entity in railway yard plane; in the process of designing, we also did a focused research on associated design of equipment in railway yard, and preliminarily realized linkage design of plane railway yard.

Acknowledgement

This paper is supported by Yibin Port on the Development of Research and Regional Economic Interaction (SYJJ2013B07)

Research on conversion of unstructured data to structured data based on XML technology (QJ05-03).

References

[1] DURMUŞ, M. S., YILDIRIM, U., & SÖYLEMEZ, M. T., 2010. Signalization and interlocking design for a railway yard: A supervisory control approach by enabling arcs. In *The 7th International Symposium on Intelligent and Manufacturing Systems*. IMS 2010.

[2] GAMON, W., 2015. Movement analysis of cooperating railway buffer heads. *Archives of Transport*, 33(1), pp. 7-15.

[3] GAO, F., ZHANG, D.W., ZHANG, J.G., 2011. Induction hardening and deformation control of rail components for high-speed railway turnout. *Heat Treatment of Metals*, 36(3), pp. 103-105.

[4] KARDAS-CINAL, E., 2014. Selected problems in railway vehicle dynamics related to running safety. *Archives of Transport*, 31(3), pp. 37-45.

[5] KRISHNAPILLAI, R., ZEID, A., 2006. Mapping Product Design Specification for

Mass Customization. *Journal of Intelligent Manufacturing,* 17(1), pp. 29-43.

[6] LI, X., ZHANG, J., FAN, X., 2015. Computer Aided Railway Yard Design. C. International Conference on Transportation Engineering 2009ASCE, pp. 451-457.

[7] LIANG, M. A., GUO, J., CHEN, G. W., 2013. Design of Wagon-Flow Simulation System of Railway Marshalling Yard Based on J2EE. *Journal of System Simulation*, 25(5), pp. 1083-1089.

[8] LIU, M., NING, T., ZHU, Z., 2012. Research and development on computer aided design and optimization system of steel grating. *Journal of Graphics*, 33(4), pp.59-63.

[9] PENG, B., ZHANG, N., & GAO, Y. L., 2014. Static and Dynamic Analysis of Railway Reinforced System with Cross-Beams. *Mathematical Problems in Engineering*, *2014*.

[10] QING-YUAN, X, 2003. Analysis of Longitudinal Force and Displacement of Seamless Turnout with Finite Element Methodology. *China Railway Science,* 24(6), pp. 36-40.

[11] ROANES-LOZANO, E., ROANES-MACÍAS, E., LAITA, L.M., 2002. A computer algebra approach to the design of routes and the study of their compatibility in a railway interlocking. *Mathematics & Computers in Simulation*, 58(01), pp. 203-214.

[12] THURAISINGHAM, B., 2007. Security and privacy for multimedia database management systems. *Multimedia Tools & Applications*, 33(1), pp. 13-29.

[13] YANG, T., 2006. Recognizing of the Sketch of the Station Bottleneck and Its Optimized Design Model Based on Constrained Reasoning. *Journal of the China Railway Society*, 28(2), pp. 1-6.

[14] YUAN, C., WU, Q., YUAN, H., & FENG, Z., 2014. Optimization of Urban Public Transport Network Considering Rail Transit Interaction Effect. *Journal of Highway & Transportation Research & Development*, 31(8), pp.119-125.

[15] ZHAI, W., JIN, X., ZHAO, Y., 2010. Some typical mechanics problems in high-speed railway engineering. *Advances in Mechanics*, 40(4), pp. 358-374.

[16] ZHOU, X., 2013. Formal method of product design in mass customization based on theory of polychromatic sets. *Application Research of Computers*, 30(11), pp. 3362-3357.

[17] ZHU, G., 2008. Arithmetic Design in Inspecting Consistency of Railway Signal Station's Graph. *Computer Measurement & Control*, 16(10), pp.1382-1379.