ICIC Express Letters
Part B: Applications
Volume **8**, Number **4**, April **2017**

 ISSN 2185-2766
pp. **795–802**

UNIVERSAL DESIGN MODEL OF INNOVATIVE SPACE DESIGN IN BUILDING RAILWAY STATIONS IN TAIWAN: A CASE STUDY OF TEN STATIONS

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Received September 2016; accepted December 2016

Abstract. *In recent years, the Taiwan Ministry of Transportation and Communications has been advocating the improvement of public transportation. Among these improvements, the rebuilding of intercity public transportation stations and updating of vehicles are the two essential concerns. In this paper, we examine 10 recently built elevated train stations in Taichung metropolitan area. We examine the different spatial uses of the stations and their fulfillment of users' functional requirements, and emphasize the user-friendliness of the service environment, convenience, and safety design. Stations should not only aim to satisfy users' traveling requirements but also to integrate the stations' operational functions to meet the requirements of employees. To integrate the stations' operational functions as a whole, the researchers studied and planned regarding the construction-related services of the stations, including transport services, public works, maintenance and service systems, electrical performance, and other functional requirements of the space. Emphasis was placed on the integration of the planning and design of the space's interoperability. Travelers' requirements, from their wait for the transportation to their travel on the train, were considered, focusing on the use of the public space and the dissemination of information to travelers. The aim was to create a multifunctional station and barrier-free environment for elderly and disabled travelers, in which convenient, and user-friendly equipment and a safe environment are provided for people of all ages.*

Keywords: Railway stations, Universal design, Information and communication technology

1. **Introduction.** The construction of the Taiwan railway system began with the Western Line in 1887, with the first section from Taipei to Keelung being completed in 1891. The second section, from Taipei to Hsinchu, was completed in 1893. The rest of the Western Line was finished in 1908, with the inauguration held at Taichung Park on October 24, 1908. The construction of the Eastern Line started in 1910, with the northern Yilan section being finished in 1924 and the southern Taitung section being completed in 1926. The Northeast Corridor Line was finished in 1980. The final link in the round-island railway system was the Southern Corridor Line, which was completed in 1992 [1].

The government of Taiwan has been promoting a railroad transportation renewal plan, and has adopted the concept of universal design (UD) [2]. Building new stations and fixing the railroad routes have become major economic developments and urban renewal projects in cities in central Taiwan. However, the station planning and the integration of the buildings regarding the use of space have typically been undertaken with a lack of comprehensive considerations, thereby negatively affecting the satisfaction of travelers. For example, the requirements of riding direction flow, dissemination of information,

FIGURE 1. Taichung railway stations

transport connection, waiting spaces, and barrier-free environments were usually not considered and were not integrated fully when the stations were constructed (Figure 1) [3]. These shortcomings reduce convenience for users, negatively affecting their attitudes toward the railway service. The application of UD provides service operators with deeper insight into the "who, when, where, and what" of the station buildings; thus, operators are able to implement more efficient use of space for people using the building and create an optimal situation for users, managers, and station owners.

In this paper, we construct an innovative functionally integrated planning model to fulfill the requirements of railway station building space that can address the shortcomings of traditional railway station designs with respect to space construction. On the basis of traffic characteristics and previous experience of station renewal, we provide an innovative plan for the construction of "new generation stations".

Stations should be multifunctional and barrier-free environments that integrate the functional requirements of the operating personnel and management [4]. The implementation of the "generalization" and "application" aspects of the station plan provides elderly adults, children, pregnant women, and disabled people with user-friendly services, thereby providing all users with a safer and more convenient environment [5].

2. **Station Construction Planning and Conceptual Framework.** This paper discusses the requirements and functions of the 10 elevated stations in Taichung. Evolving social values has to lead to stations focusing on users' rights and requirements. Therefore, building a new generation station entails constructing a "compounded" and "diversified" space, which is an essential concern in contemporary station planning and design. Thus, this paper applies analysis, integration, and induction to developing more practical, professional, and innovative theories and strategies for future stations. Thus, future stations

will benefit users, accommodate their rights, assist their operating departments and facilitate convenient maintenance. Furthermore, the potential for the government to change the building program or revise the budget can be avoided. The purpose of this study can be summarized as follows.

(1) Research and analyze station construction planning, and ensure combined consideration and countermeasures.
(2) Explain the requirements for station buildings to satisfy users.
(3) Construct new generation station buildings that have optimal operating performance, maintenance, spatial integration, carbon footprint reduction, and sustainable development for reference.

In summary, to provide travelers and operators with the optimal plan for the use of space in new generation stations, addressing users' demands is the most effective strategy and the key factor in promoting public transportation policy and implementing local transportation development.

3. **Methods.** This study used 10 recently built elevated railroad stations in Taichung metropolitan area as research objects and investigated them by using interviews with experts and statistical analysis of questionnaires. Questionnaire-based interviews were conducted with eight engineers in related fields, and transcripts of the interviews were produced. In addition, we used questionnaire surveys and distributed 550 written questionnaires. We retrieved 322 valid questionnaires, with an effective response rate of 58.5%. Furthermore, we used online surveys and distributed 450 written questionnaires, from which we retrieved 334 valid questionnaires, with an effective response rate of 74.2%. A summary of the statistics regarding the questionnaire is shown below (Table 1 and Figure 2). The operational requirements for the station are shown in Table 2.

Hermeneutic phenomenology [6] can be applied to qualitative research [7] to comprehensively analyzing railway station space requirements and performance (Figure 3) and thereby facilitating advanced planning and design, as well as achieving reintegration of the UD perspective into the space and function of stations. Moreover, the reintegration of the UD perspective into the space and function of stations can enable achieving overall benefits, optimizing innovative station space, and realizing performance strategies. Factors such as user-friendliness, composite design, and diversification are thus combined with information, communications, electronics, control and management technology, as well as rail transport hardware and software, thereby providing fully automated operation for the station management. This can be termed an "intelligent transportation system". The implementation of this planning model upgrades service quality and efficiency, enables credible programs to establish the optimal use of space design selection, and provides

Table 1. Statistics for UD innovative space design questionnaires

Item	Questionnaire	Copies	Total		Effective response rate (%)	Sub-total effective response rate (%)	Total effective response rate (%)
Written questionnaires	Valid questionnaire	322	550	1000	32%	58.5%	65.6%
	Invalid questionnaire	228			23%		
Online survey	Valid questionnaire	334	450		33%	74.2%	
	Invalid questionnaire	116			12%		

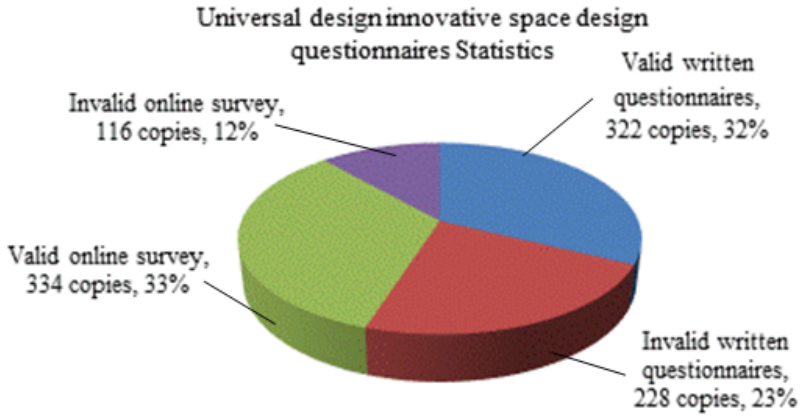

FIGURE 2. Questionnaire chart

TABLE 2. Operational requirements

Item	Operational requirements	Attributes	Remarks
1	Basic operational requirements of building space station for each grade	Public works facility	
2	Integrate the ICT requirement of smart buildings station	Electric service facilities	
3	Demand of current workers in station	Transportation service facilities	
4	Service quality, environment, safety, convenience and consistency demand for passengers	Maintenance facilities	
5	Strategy of travel planning and depot facilities space design for station	Depot facilities	
6	Countermeasures for installing environ-mental friendliness and guide index system	Depot facilities	

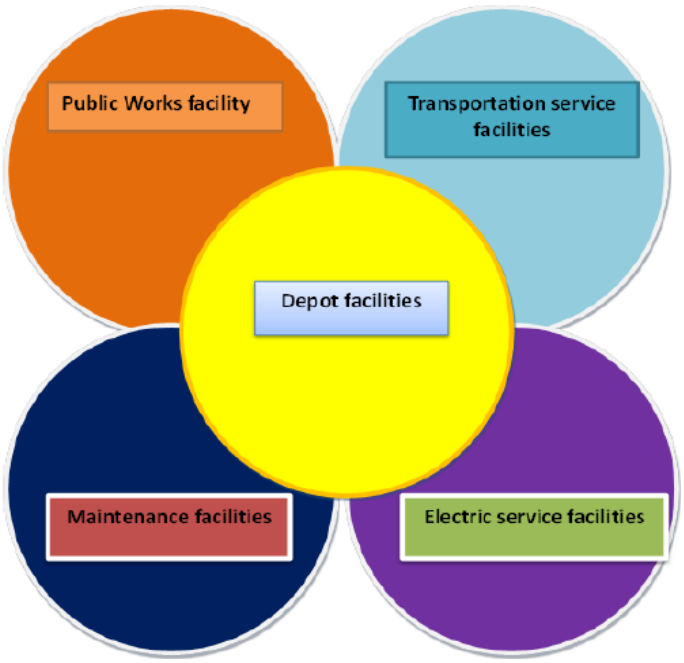

FIGURE 3. Requirements of station planning

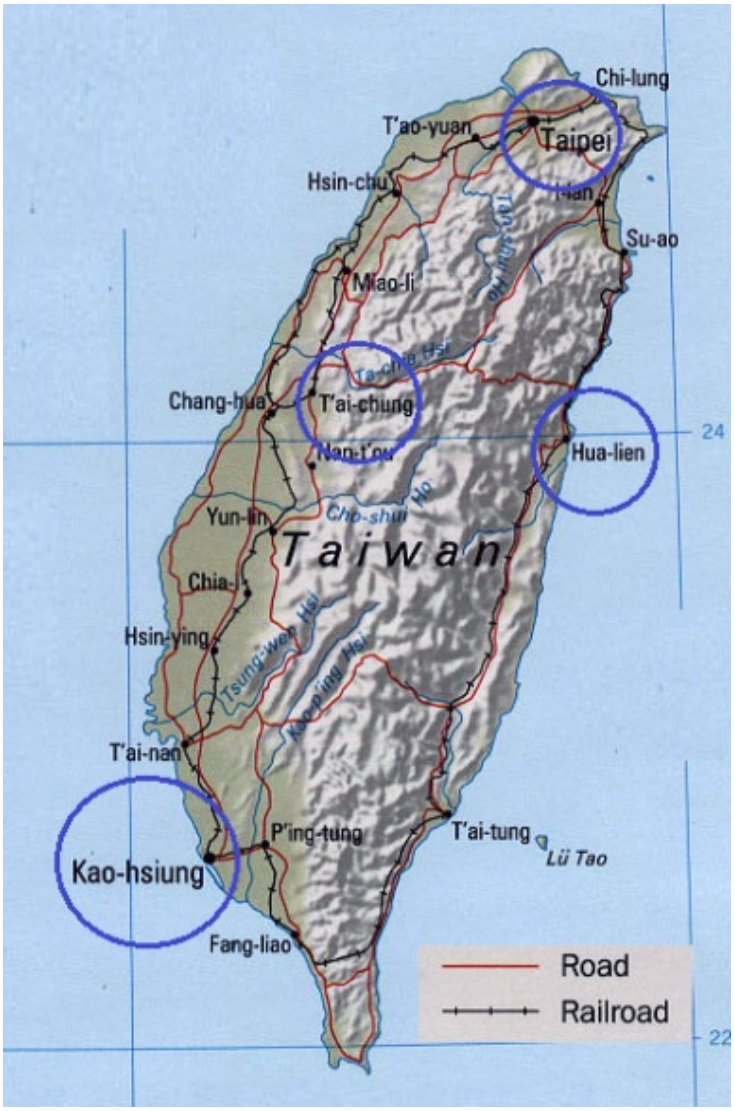

FIGURE 4. Taiwan rail networks

FIGURE 5. Taichung station and surrounding area before and after development

TABLE 3. Required spatial planning items for station

Line item	Public/Depot system space	Facilities and equipment properties	Line item	Public/Depot system space	Facilities and equipment properties
1	Public Area Spaces	Unpaid Area	7	ELVR Space	Barrier-free Elevator
		Paid Area			Escalator
2	Business Management Administrative Space Station	Passenger Service	8	Transfers Facilities Space	Parking Space
		Executive Space			Temporary Parking Space
3	E/M Equipment	Signal System	9	Rolling Stock, Electricity (Signal) and Engineering Building	Civil Engineering Office
		Central Supervisory and Remote Control			Electricity Office
4	Electricity Power System Space	Transport Power System			Signal Office
		General Electric Power Systems			Transformer Substation
5	Communication System Space	Cable and Radio Electronic System			Relay Room
6	Water and Environmental System Space	Water Supply and Drainage Machinery Space			Track Team Workstations
		Environmental Control Machinery Space			Optical Line Transmission Equipment
		Fire Fighting Machinery Space			Police Station

government agencies, planners, and designers with a reference for enhancing the planning and design performance of new generation stations.

To achieve the target UD design, we used Taipei Main Station, Kaohsiung Station, and other main stations as auxiliary objects (Figure 4) [8]. In addition, we used Taiwan High Speed Rail, metro systems, and bus networks, as well as other transport interchange systems as references. We referred to the operating status of the stations of the area before and after development (Figure 5). The on-site surveys used the subject as a check item for the spatial planning and design requirements of new stations.

Facilities required for organizing the station space, including systems for boarding process planning, transportation marking, accessibility, information interchange, and traffic management of the area around the station, are listed in Table 3.

4. **Innovative Design Requirements and Functions of Stations.** The planning strategy and design targets of station spaces must apply passenger-oriented concepts that enhance diversity and inclusiveness [9]. To integrate materials, shapes, structures, physical environmental controls, appropriate construction equipment and safe surroundings, visual senses, textures, color, ventilation, lighting, sound control, water supply, drainage, electricity, air conditioning, fire safety, and other functions [10], all facilities require a standard design process that integrates the distributed architecture and functional working of the station and meets "capital, pass, hearing" system requirements [11]. Finally, a new generation station with beautiful architecture can be created (Figure 6) [12], thereby realizing a green, innovative city.

For requirements such as service operation, user-friendliness, and versatility, Table 4 indicates the necessary mechanization processes identified by this survey.

5. **Conclusions and Recommendations.**

5.1. **Conclusions.** This article investigated the overall planning for future railway stations with respect to designer functionality demands and passenger-friendly requirements. The inclusion of intelligence space, electronic ticketing system, and ipass is achieved as follows.

FIGURE 6. Ten elevated stations for a green, innovative city in Taichung

TABLE 4. Functional and operational requirements for overall construction planning

Line item	Camp transport demand	Innovative planning machine	Property
1	Each grade architectural space station operational needs part	(1) Functional spatial normalization	Public works facility
		(2) Space of consistent indicators guide	
		(3) Smart device capabilities unification	
2	Smarter buildings owned station, pass, part of the demand function news	(1) Forming a customized bus station information network	Electric service facilities
		(2) Value-added application service station of the cloud feedback	
		(3) Real-time video application system of value-added services	
		(4) Travel and information platform integration means facilitation	
3	Most operating station workers demand	(1) Operating equipment functioning fully automated	Transportation service facilities
		(2) Safe and high quality of service environment	
		(3) Multi-objective operational value of the station	
4	Planning space station facilities design strategy part	(1) Systematic function space	Maintenance facilities
		(2) Multi-functional space functional device	
		(3) Controls smart diversification	
5	Most passenger service requirements	(1) Identification of the vehicle path facilitation	Depot facilities
		(2) Pick-up and comfortable environment close to the people waiting	
		(3) Affect a warm and friendly environment and facilities	
6	Environmental friendliness and build part of the guidance system	(1) Transfer station interactive information integration	Depot facilities
		(2) Combined with local tourism and cultural characteristics of the industry	
		(3) Driving the integration of information transparency instant messenger	

(1) Passenger friendliness should be the focus of station planning.
(2) Environmental friendliness is with a lower carbon footprint.
(3) Integrate the P, D, C, A standardization method to improve space planning, customer satisfaction, and maintenance costs.
(4) Elevated stations have the following benefits: enhanced land management, reduced crossing accidents, less underpass flooding damage.
(5) Future stations should combine green building concepts with local business integration.

The new generation station approach adopts the smart green buildings design concept, which is based on information communication and security management. Not only does this approach entail energy conservation and an emphasis on beauty, but it also improves economic development and cultural character, reducing the burden placed on the natural environment. New generation stations will be landmarks of the cities in the future.

5.2. **Recommendations.** Applying the style of a traditional historic station building and involving the local government to urban planning is advisable. Reviewing the overall cultural and innovation value is also recommended, as well as introducing historical monuments. Thus, the combination of station buildings and cultural history can create an optimal situation. New generation stations will eventually become international city landmarks and city sightseeing highlights.

(1) All interested stakeholders should be included in the planning stage of the station to reduce possible conflicts during development.
(2) Historical station architecture should be revitalized.
(3) Reviewing the rail system transportation demands, reducing the interfaces in planning, design and construction, and adopting optimized plans (elevated, underground, or level crossing) are necessary, as is employing staged construction to reduce costs.

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