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Establishment of Urban Rail Safety Protection and Emergency Management Education Framework Integrating STEM & PCOM Matrix

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Abstract: From the perspective of systems engineering, apart from the technical reasons of the rail transit itself, the deficiencies in planning and design, as well as the misunderstandings of various professional operation managers regarding the use of rail transit equipment and emergency evacuation, are all the causes of the frequent occurrence of rail transit accidents. A systematic knowledge system covering multiple links and targeting multiple objects for rail transit risks is of vital importance. This thesis focuses on the planning, construction, operation, passenger organization and emergency management of rail transit, and constructs a system of basic consensus, professional knowledge, safety protection and key technical points for emergency response. The aim is to establish a common understanding basis for all kinds of people, including planners, constructors, operators and passengers, regarding each link of rail transit, and break through the knowledge blind spots and barriers caused by thinking inertia, professional limitations and cognitive differences. This paper proposes the concept of "PCOM's full-process safety and emergency management control" for the urban rail transit safety and emergency management major and courses, and constructs a course matrix based on the STEM concept, the proposed matrix that includes science, technology, engineering, and mathematics, as well as planning, construction, operation and emergency processes. This kind of matrix construction is conducive to enhancing the practicality and systematic level of higher education when conducting course education in complex scenarios such as urban rail transit operations.

Keywords: Urban Rail; STEM; PCOM; AI; Matrix; Education System Framework.

1. Introduction

In China, currently there are approximately 60 cities operating 308 rail lines with a total operating mileage exceeding 10,000 kilometers. In 2024, the cumulative passenger volume throughout the year has exceed 2 billion. Urban rail transit is a century-long project. This refers not only to the long duration of the entire process from exploration, planning, design, construction to operation of rail transit, but also to the high requirements for the quality of rail transit projects and operational safety. The planning, construction and operation of rail transit should be closely linked. The practitioners and participants in each link need to have a relatively complete, systematic and comprehensive knowledge system, that is, general knowledge about rail transit. Analyzing cases such as the water disaster in Zhengzhou subway tunnels, the elevator reversal at Beijing Zoo Station, and typical rail transit accidents abroad, when facing millions of passengers, how to effectively prevent risks and build safe and resilient rail transit is a major issue.

According to the"14th Five-Year National Security System Plan" and the"14th Five-Year National Emergency System Plan" formulated and released by the Chinese national government, cities will undoubtedly become the main battlefield for China's future security control and emergency response. Urban rail transit, due to its physical characteristics and important role, is of paramount importance and is also the key point for professional education and training in areas such as urban management and intelligent emergency response. In recent years, the subway networks in cities, especially some megacities, have basically taken shape, presenting typical characteristics of being fully networked and covering large areas. There are many gaps in cross-provincial, multi-party collaborative management systems, station management within different provinces, emergency response, command and dispatch, and the allocation of emergency rescue forces, as well as all related regulations and management systems. This is also a gap in higher education for practical-oriented talents in rail transit.

(1) Rail transit plays an irreplaceable role in providing safe, economical, and reliable transportation services to ensure large-scale traffic demands and maintain the stable daily production and living of cities. Establishing a risk identification system engineering framework for rail transit and creating a foundation covering the general knowledge of rail transit for all types of people, including planners, constructors, and passengers, is an inevitable requirement for maintaining the resilience of rail transit.

(2) The pressure and challenges faced by the management of the rail transit industry are increasing. In the current frequent emergency situations, establishing an effective communication platform between operators and large

passenger groups depends on all participants having a consensus on the risks and emergency response of rail transit. Especially in the context of the informatization era, achieving interoperability, sharing, and rapid collaborative linkage of information among multiple operating entities and various types of passengers, guiding large-scale passenger flows orderly, avoiding congestion, is the core technology of urban rail transit emergency dispatch and command.

The risks of the rail transit system are highly correlated, have diverse spreading characteristics, and have a huge impact range. A single discipline and traditional technology are difficult to meet the requirements of the typical complex network collaborative management of rail transit, especially the new spatial form of rail transit within cross-provincial metropolitan areas and the problem of multi-party management integration are increasingly prominent. The requirements for large-scale and collaborative management are getting higher and higher, and it is required that rail transit management talents should not only have a traditional science and engineering background but also have a vision and perspective in spatial science and system science.

2. The Construction of Teaching Concepts for Urban Rail Transit from the Perspectives of Control Science and System Engineering

In China, the most important goal of higher education is employment. The research objects of fields such as urban management, urban safety technology, and urban rail transit are cities. Correspondingly, the curriculum and teaching system established in university higher education should also correspond to the characteristics and laws of cities, and more importantly, consider the demands of various job positions in the city. Because a city is a complex large system, many scholars have conducted a lot of research in areas such as how to establish and enhance the resilience of cities, the flexibility and resilience of urban rail transit operation management, etc, that include Marchese, D. et al. drew on the concepts of ecological system resilience and sustainable development for urban management research[1]. Wei, B.,et al.(2025)analyzed the relationship between the resilience of urban rail transit and the stable operation of the city[2],Besinovic, N.et al.(2020) systematically summarized the research on the resilience of urban rail transit systems[3],Ma, Z.et al.(2022)from a quantitative perspective, studied the measurement and evaluation methods of the resilience of urban rail transit, Huang, H.,et al.(2023) conducted a systematic summary of urban resilience in China. Specifically in the field of rail transit resilience, Wen, X.et al.(2025)systematically summarized the evaluation methods for the resilience of urban rail transit in China[6], Yadav, N.et al.(2020)conducted specific case studies on the maintenance and evaluation of urban resilience in some specific disaster scenarios[7].Cities are resilient, and accordingly, higher education should also be resilient. Lehmann,M.,et al. (2008)proposed the educational concept of continuous learning to adapt to sustainable urban development based on the idea of urban resilience [8].

The above is a summary of the application of the resilience concept in higher education for fields such as urban science, urban management, urban safety technology, and urban rail transit operation management. This belongs to the horizontal level, meaning that the resilience concept will be applied in various university majors including urban rail transit safety operation.

On another level, the detailed directions involved in urban rail transit are also very diverse. In the various aspects of urban rail transit planning, construction, operation, and emergency response, different technical methods have led to new integration. This belongs to the vertical level of integration.

In the field of urban safety, rail transit is highly representative, and its features typical multi-disciplinary integration, rich scenarios, and comprehensive coverage of people, events, and principles. From the theoretical and technical perspectives, the professional route and fields of urban rail transit safety prevention and management are long and difficult. Due to the systematic, comprehensive, and complex characteristics of cities, currently, the professional education and training in urban management and intelligent emergency response at various universities show obvious characteristics of inclusiveness. Li,C.et al.(2025)analyzed the safety resilience issues of underground space in the rail transit systems of 26 cities in China and proposed the Pressure-State-Response 3-level model. This model has certain reference value for the corresponding higher education teaching design[9].At the planning level, Zhu,J.et al.(2014)proposed a framework for the planning and construction of smart cities[10].Tao,S.et al.(2021) conducted a study on the application of big data technology in urban security control and emergency management in the field of higher education[11].Anna,S.et al.(2013)proposed the application of computer simulation technology in higher education [12]. Correspondingly, the research conducted by Sun, C.H.,et al.(2025)focused on the field of urban rail transit safety control and emergency management. It utilized an intelligent network offline teaching model based on a machine simulation system to enhance the quality of talent cultivation for urban rail transit management, this study introduces a design approach for an undercarriage robot simulation system and an offline teaching method[13].Li,J. (2024) proposed the establishment of an educational system for the concepts of safety and emergency response in urban rail transit systems[14].Hu,A.N. et al.(2015) conducted an analysis on the shortcomings of the STEM concept in fields such as urban management and urban security based on the context of university education in China[15].Shchedrina,E. et al.(2020) analyzed the integration issue of modern mobile-based teaching and traditional skill training teaching in STEM education[16].Li,J.et al.(2024)focused on a specific course in Chinese university teaching and established a framework for the course on Urban Rail Transit Safety and Emergency[17].

It is common to draw on related or similar professional contents, including GIS, underground space engineering, and transportation engineering, or for each school, directly selecting multiple professional courses for combination to form the curriculum system of this major.

In addition, many studies have taken a more comprehensive approach, analyzing the development prospects of the profession as well. Yue,Q.(2024) analyzed the various challenges faced by emergency management, urban security technology and other related majors in China's higher education reform, particularly the difficulties encountered by local ordinary universities in China[18].

In summary, the rail transit sector in China is currently in a crucial period of significant construction and transformation[19]. Overall, based on actual cases of urban rail transit (such as the large-scale water flooding disaster in

Zhengzhou Metro in China, and the fire incident in Daegu Metro in South Korea), and by leveraging complex network and system control theories to analyze and model the static characteristics and meso-microscopic dynamic features of the various levels of the urban rail transit network, and on this basis to condense, summarize, enhance, and transform for teaching purposes, and to draw lessons by analogy in conducting practical teaching summaries at all levels and in all fields of urban rail transit, this is not ideal. Moreover, the achievements of applying AI empowerment for auxiliary teaching in teaching are even rarer.

The safety management and emergency response work of urban rail transit demands high levels of specialization and collaboration. All managers involved in urban rail transit safety emergency control must not only master traditional basic professional methods of risk prevention and control, but also need to possess the ability to handle urban multi-scenario emergencies, especially new and complex accidents. With the continuous increase of various uncertain factors affecting the normal operation of cities, the requirements for the scheduling, command, and organizational capabilities of front-line managers are also higher. It is urgent to conduct scenario design using big data technology and generate more targeted training practice models and teaching contents through AI design. This paper proposes to focus on the two core contents of informatization and intelligence, boldly improve the teaching content and teaching methods, gradually perfect the educational concept of "traceback inversion deduction" and "from practice to practice", and create a "truly operational, market-oriented, and frontline-oriented three-dimensional OBE positioning, cross-integration of traceback and inversion dual main lines" specialized and innovative integration route. The project results include: Firstly, it can integrate the perspectives of urban rail transit front-line planners, constructors, operators, and emergency personnel with university teachers, analyzing and modeling the static characteristics at all levels and the dynamic characteristics at the microscale of urban disaster prevention, mitigation, and relief using complex network and system control theories, which has practical significance, theoretical value, and the effect of improving teaching level. Secondly, through refinement, summary, enhancement, and teaching transforma -tion, using traversal and AI empowerment to continuously generate cases, enriching the teaching efficacy of big data robots, it can draw lessons from one case to apply to multiple cases in urban rail transit safety emergency control in various links and fields, fully adapting to the requirements of the future development trend of higher education in cultivating urban rail transit safety emergency talents.

3. The Application Value of Traditional Embroidery in Modern Fashion Design

(1) STEM

STEM is a very popular concept in higher education particularly in general education and engineering disciplines, it is the acronym for science, technology, engineering and mathematics.In general, the concept of STEM emphasizes interdisciplinary education to cultivate comprehensive practical abilities. This concept originated in the United States of America. The "Undergraduate Science, Mathematics and Engineering Education" report in 1986 first proposed the SMET framework; the"American Competitiveness Initiative" in 2006 listed it as a national strategy[15][16]; the "STEM Education Act" in 2015 officially defined the subject scope; and the "STEM 2026" plan set six development visions. China first advocated exploring STEM education in the "13th Five-Year Plan for Education Informatization" in 2016.

(2)PCOM

Establishing a modern risk identification system for the entire process and entire chain of rail transit is an inevitable requirement of history. Analyzing from a chronological and systematic perspective, the problems presented by rail transit are the concentrated manifestation of inherent defects and mutual influences in the planning, construction, operation, and various equipment and facilities systems during each stage and of the systems themselves, and are the fundamental guarantee for determining the operational safety status and level of rail transit networks.

By integrating knowledge from multiple disciplines, we comprehensively review the technical key points in all aspects of rail transit, including exploration, planning, design, construction, operation, and emergency response. We summarize and refine the rail transit system from a systematic scientific and engineering perspective.

Adopting a multi-mapping combination and multi-dimensional integration, multi-mainline connection technology approach, this paper sort out and explain the process and key points of rail transit exploration, planning, design, construction at the technical level. We summarize and analyze the interrelationships and mutual constraints of the rail transit operation system at the phenomenon level. We extract and explain the conditions and environments for the safe travel and evacuation emergency of a large number of passengers at the service level. We use mind maps, ergonomics, and system dynamics to construct a graphical, structured, and hierarchical knowledge base for rail transit system knowledge.

In the design of the curriculum system for rail transit safety and emergency, it is more effective to combine with China's national urban agglomeration development strategy. This includes identifying the characteristics of the complex and large-scale rail transit system, integrating regional development characteristics, especially focusing on the "passenger cross-provincial travel and safety management separation" feature that appears in cross-administrative region rail lines in China. We identify the characteristics in operation, safety planning, emergency response, etc. in these aspects.

4. AI Enables the Construction of Teaching Resources and Involves Business and Technical Issues

(1) Establishment of teaching resources and corresponding business review

Urban rail transit emergencies are manifestations, with the root cause lying in the accumulation of various hidden dangers, defects, and management lapses at all stages of planning, construction, operation, and emergency response, leading to system instability. Planning, construction, operation, and emergency response are a systematic whole. To effectively identify risks, manage and control them, and enhance the level and capacity of intelligence, it is necessary to start from the following aspects to establish a systematic technical and management system.

Establishment of a systematic knowledge base for urban rail transit fundamentals.

From the perspective of systems engineering, the rail transit system at the line level is a multi-dimensional object including train operation organization and passenger service quality. At the node level, it reflects the matching between passenger flow and equipment, facilities, and infrastructure structures, and its essence is the form of passenger flow presented in the time and space axes, which is a key point related to safe passenger travel.

The rail transit network is not merely a simple physical collection of lines, but a complex system that confronts multiple systems. There are significant constraints and interferences between lines, and risks are transferred, spread, and escalated in various forms. On the one hand, the risks of a single line are easily expanded and escalated in the network environment. On the other hand, the risks of this line may come from other lines, which is a key point related to high-quality passenger travel.

Rail transit is a composite system combining a spatial network and a traffic network. Trains run along lines, and passengers travel across lines. How to expand an operational safety issue from one location, define the degree of influence in each stage, and conduct standardized comparisons of the operational safety conditions of different lines is a key point related to the overall operational efficiency of the city.

The urban rail transit network also includes several different-sized and scaled line units. How to consider the characteristics of each line in the axis domain, passenger load and other factors, and achieve relatively fair and reasonable network flow guidance domain control is a key point related to passenger travel costs and the efficient operation of the basic transportation support system of the city.

Carry out research and system construction on the dissemination methods of basic consensus, professional knowledge, safety protection, and key points of emergency response techniques for each link of rail transit planning, construction, operation, passenger organization, and emergency response, aiming to establish a comprehensive knowledge base covering the general knowledge of rail transit for all types of people, including planners, constructors, operators, and passengers.

Establishment of the "Rail Transit Planning, Construction, Operation, and Emergency Response System Risk Identification System".

Based on the establishment of the general knowledge base, collect a large number of urban rail transit event cases from both domestic and foreign cities, deeply analyze the root causes of the events, start from the origin, conduct systematic analysis of the first type of risk source, the second type of risk source, and their coupling relationships, construct a correlation graph of each system and each participant in rail transit, and apply system dynamics and other methods to interpret the causes, evolution process, and key points of emergency rescue and disposal of rail transit events. On this basis, compile the "Rail Transit Planning, Construction, Operation, and Emergency Response System Safety Knowledge System".

(2)Establishing teaching resources addresses corresponding technical issues

Key issues in the establishment of the knowledge map corresponding to the teaching process. The object of the safety emergency control in rail transit is a complex system integrating physical, human, and matter aspects, featuring comprehensiveness, professionalism, complexity, and dynamics. Natural disasters, planning flaws, and management negligence can all form causal chains. This project aims to establish a comprehensive cognitive foundation for urban rail transit safety emergency control covering all aspects, by constructing a system of basic consensus, professional knowledge, safety protection, and key points for emergency response. It breaks through knowledge blind spots and barriers caused by thinking inertia, professional limitations, and cognitive differences.

Key issues in the construction of the business map through OBE. By sorting out and analyzing the multi-stage and multi-party demands in the new situation for disaster prevention, mitigation, and relief, and integrating the perspectives of front-line planners, constructors, operators, and emergency personnel with university teachers, this project will analyze and model the static characteristics and dynamic features at the meso-scale of actual cases in urban rail transit safety emergency control using complex networks and system control theories, and construct a business map for urban rail transit safety emergency control.

Key issues in the construction of a multi-mapping teaching system for knowledge maps and business maps. Fully integrate science, technology, information, and management, establish a multi-mapping combined teaching system, and express it in a diagrammatic, structured, and hierarchical manner to form a practical teaching plan. At the same time, strive to solve the problem of enhancing teaching resilience, flexibly combine and expand the practical teaching system for training and practice, summarize and refine the general requirements, rules, and practices for the entire process and chain of emergency in urban rail transit safety emergency control, including emergency scenarios, dispatching and command, and application of information systems, etc., with a focus on including emergency scenarios and dispatching and command.

Key issues in the growth of big data-assisted teaching and AI integration. Build a modular and flexible-combined AI-assisted matrix teaching and practical implementation system. In the teaching technology design route, take the construction of a big data robot teaching system as the basic platform. Use traversal and AI empowerment to continuously generate cases, integrate AI for secondary creation, solve the problem of AI-enabled self-organization and self-generation, support the automatic generation and dynamic adjustment of the teaching system for case-based urban rail transit safety emergency control.

5. Construction and Function of the AI-Enabled Teaching System

(1) The role of AI empowerment

The basic consensus, professional knowledge, safety protection, and emergency handling key points system established in this paper, as well as the comprehensive urban rail transit safety emergency management general cognition foundation covering all links, can effectively break through the knowledge blind spots and barriers in disaster prevention, mitigation and relief caused by thinking inertia, professional limitations and cognitive differences.

The business map and knowledge map established by this paper through OBE reverse reasoning can effectively enhance the graphical, structured and hierarchical expression level of the case-based teaching system for urban rail transit safety emergency management, providing technical guarantees at the technical level for the possibility and efficiency of AI

empowerment, and forming a feasible teaching plan at the teaching level. It can be flexibly combined and expanded through modularization based on the detection of mutually exclusive and redundant teaching contents, and solve the problems of teaching resilience evaluation and improvement.

The modular and flexible combination-supported AI-assisted matrix teaching and practical training implementation system established in this paper, with the construction of the big data robot teaching system as the basic foundation, continuously generates cases through traversal and AI empowerment, integrates AI for secondary creation, solves the problems of AI empowerment of self-organization and self-generation, supports the automatic generation and dynamic adjustment of the disaster prevention, mitigation and relief teaching system, and can fully enhance the overall resilience of professional higher education talent cultivation in future rail transit safety emergency management.

(2)AI Empowering the Construction of the STEM- PCOM System

Construction of the urban safety emergency control business system based on rail transit: Analyze and summarize the multi-stage and multi-party demands for urban rail transit safety emergency control under the new situation, and form a risk map. Through the construction of the risk identification map system, establish a comprehensive knowledge system for all stages of rail transit safety emergency control, including planning, design, operation and emergency, horizontally. From the management, prevention, treatment, control and rescue aspects, summarize and extract the general requirements, rules and practices for key links such as dispatching and command, and the application of information systems in the entire process, chain and especially emergency scenarios of urban disaster prevention and relief.

Integration of urban safety emergency control business and teaching based on rail transit: Integrate the first-line planning, construction, operation and emergency personnel of urban rail transit safety emergency control with university teachers from two perspectives, and use complex network and system control theory to analyze and model the static characteristics and dynamic features at the microscale of actual cases of urban rail transit safety control and emergency response. Establish an AI-assisted teaching model teaching system with multi-mapping combinations, and express it in graphical, structured and hierarchical forms to form a feasible teaching plan.

Construction of the basic functions for automatic production of urban safety emergency control case teaching resources: Through refinement, summary, improvement and teaching transformation, form the corresponding modularized and flexible combination-supported AI-assisted matrix teaching and practical implementation system. In the teaching technology design route, take the construction of AI-enabled auxiliary teaching system as the basic foundation, and achieve the technical basis for automatic generation of teaching cases through structured reconfiguration.

AI-enabled case self-organization and self-generation for urban safety control and emergency command: Utilize traversal and AI-enabled continuous self-generation of cases, integrate AI for secondary creation, generate a case teaching system for urban rail transit safety emergency control that covers from edge to edge and from top to bottom, and achieve the goal of automating the enrichment of big data robot teaching efficacy.

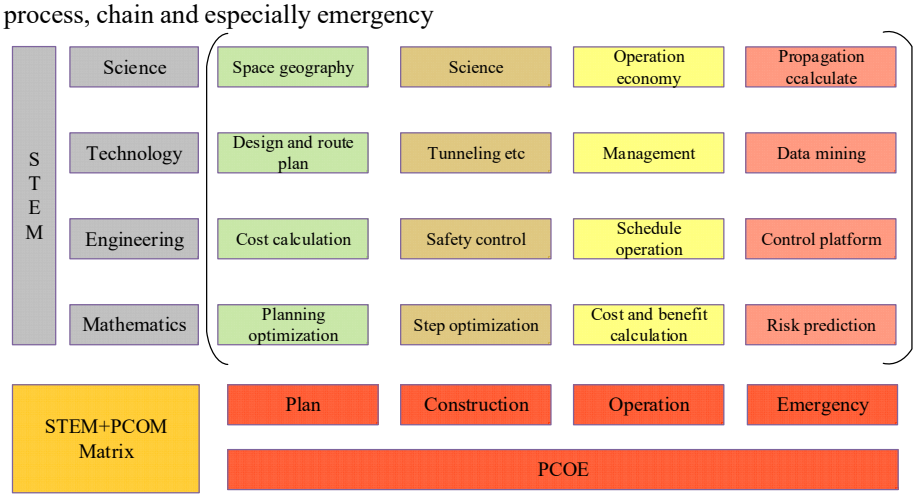


Figure 1. STEM+PCOM matrix course framework

6. Conclusion

The trend of mass data in power system provides a basis for load characteristic analysis and prediction model establishment, but the classical load forecasting method can not afford such a huge time and computing resource consumption. The problem of over fitting in large sample set will affect the prediction accuracy. In this paper, a power load forecasting model is built by using the BP neural network model, making full use of the powerful data processing function of Clementine and preventing the over fitting function. The experimental results show that the BP neural network model has good predictability and robustness, and has a certain practical application value.

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