Research on Safety Management System for China Railway

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Abstract: Along with technical progress and fast paced development in China railway, new requirements of inspecting and managing railway safety in a high-level and systematic way is challenging our traditional safety viewpoints. This paper presents an investigation of current safety management mechanism and status in China railway. Referring to the concept of safety management system (SMS), this paper proposes an applicable framework for conducting risk based evaluation principle and safety managing procedures to China railway construction in coalition with existing fundamental regulations. Also a main point of performing such framework via PDCA monitoring Loop with practical safety principle is given.

Key words: safety management system, regulation by men, risk based evaluation principle

1 Introduction

As initiated by development and manufacture, the issue of safety is universally significant for all the technical system, without exception of railway system. However, in terms of the characteristics of railway system, some particular features should as be highly emphasized as they used to be [1]:

- Dynamic safety of transport: the rolling stocks operated on the tracks will surely be in directed motion, a series of issues on transport safety, for example, wheel-rail interaction, pantograph-contact line relation, train control and route setting embodied in rolling stock with their directed motion, will apparently be handled in dynamic procedures.
- The severity of loss of safety: Once equipment exception or operation failures happened in the high-speed running system, only transient chance is permitted for mitigation and avoidance of incidents, with limited emergency measures. In addition, railway acting as service provider, has no ownership or power to control its objects of transport, so the loss of accidents will widely spread to social factors, and then greatly damage railway business image or even the authority to the government, that means immeasurable social loss.
- Repeatability of railway safety: Railway is a continual, periodic and seasonal process of production, within which various accidents and incidents occur repeatedly. Especially in China railway, year after year passenger peak transport during the Spring Festival and summer vacation, flood fighting as well as protection against drought, all have iterative effects on railway safety.
- Strong dependency on safe operation management: Railway is a typical system of system. Sorts of equipments are laid out as numerous and jumbled as circuit board, meanwhile, several dependent operation positions have to be dispersed inside the network, all of which make efficient safety management process very essential to all type of works and collaborations at all great levels.
- Environmental complexity of safe transport: the environmental factors have a serious influence on railway safe transport and are hard to control. Extreme weather conditions and adverse social factors (morality, economic conditions, political events, etc) will give an intangible intervention to safety issues.

Reviewing the world-acknowledged achievements for high-speed railway, China draws lessons

from international experiences, then independently resolves and innovates key technologies for high speed operation. These introduced highlights promote technical progress in strategic manner, and also achieve fast paced development in China. However, new features which will challenge our traditional safety viewpoints begin to reveal. Objectively, their appearance, as stated below, manifests the significance of inspecting and managing railway safety in a high-level, systematic view:

- High speed and density running: Taking the latest constructing high speed railway: Beijing-Shanghai High-speed Railway, its operational speed will reach 380km/h and plan to transit 80 million people per year in one way. Such high quality operation will pose a real challenge to guarantee safety functional equipments to perform normally under unknown conditions, especially for experiential deficiency in other comparable system.
- All-in-one functionality and equipments centralization: Wireless data link will undertake the communication between train and ground as well as the movement authority allocation instead of track circuit. As a result, wayside equipments will be downsized and centralized. It will obviously lead to safety responsibility redefinition and more safety communication for co-managing equipments.
- High-integrity software: The CTCS-L3 which is a communication based on train control system for high speed railway has been successfully developed and operated. Most of functionalities in the train control system are implemented through software, so the formal testing and analysis as well as flow control will become chief measures to assure software safety.
- New method to measure safety: Complex interactions mean that the whole system reliability is no longer equal to the summation of all related components' reliabilities. In terms of software reliability, there is even no practical evaluating method widely accepted by the practitioners.
- Highly competent staff: New requests for the staff involved in safety management should provide with a well knowledge of railway system principles but also comprehension of safety assessment and assurance procedure in relation with one's role and responsibilities.

2 Current safety management status in China

The essence of safety management is a formal arrangement, through the provision of polices, resources and processes, to ensure the safety of its work activity. An effective safety management system will help the organization involved in Railway transport to indentify and manage risk effectively. It allows an organization to demonstrate its capacity in performing its safety responsibilities and in meeting regulatory requirements [5].

In the case of railway safety management framework, there has existed a localized practical system connecting with specific implementing circumstance in China. The circumstance mentioned here is indeed a melting pot in which large numbers of factors involved take synthetic effects. To completely outline these factors needs several sophisticated organizations who have gone on to experiment widely with engineering and project management in China, but also the power to push such exploration forwards in order to progressively elaborate as much factors as they supposed to be.

2.1 Legislation basis

In China, safety standards are enacted in the form of legal provision. The clauses listed in these standards represent behavior constraints of practitioners particularly involved in railway operation and management. A primary legislation structure for safety management is drawn in Fig 1.

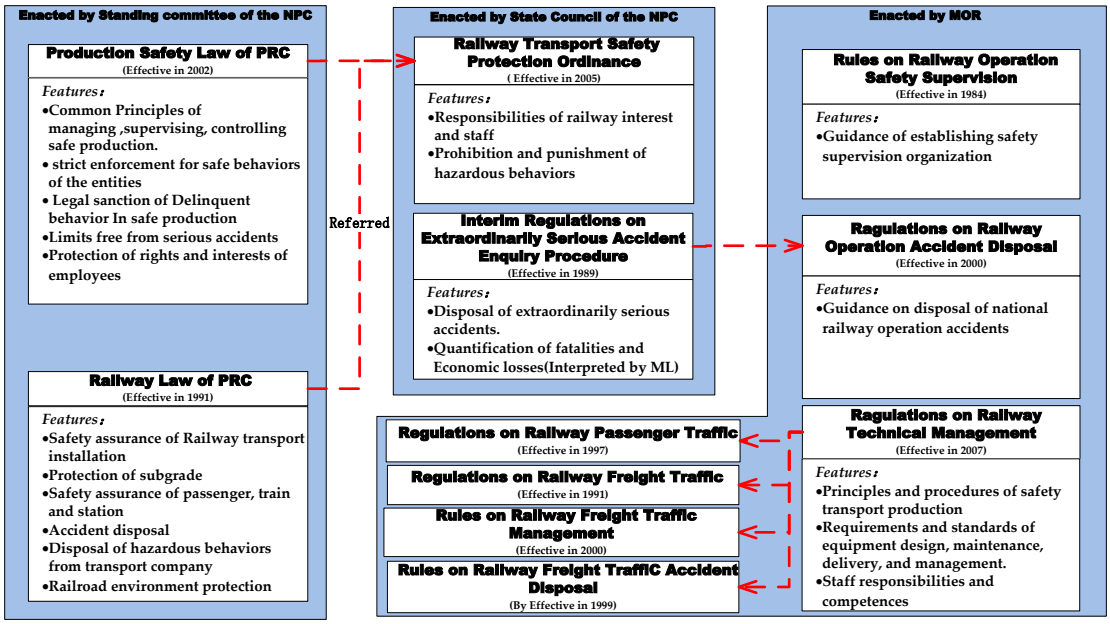

Figure 1. Railway safety legislation in China

The laws and regulations enacted by each rank of regulatory agency (Standing Committee, State Council, and Ministry of Railway) are orchestrated in three strands:

- Accident disposal: involving accident classification, enquiry, statistic, analysis, report and announcement;
- Safety supervision: involving legal responsibility of institution, leadership and competence of safety supervisor.
- Operational management: involving principles and procedures of safety production and operation

In each strands, related regulations will be updated in accordance with newly technologies or operations applied in railway domain. And what we select in this figure are fundamental regulations, other domain-specific complementary rules are not mentioned for reasons of space.

2.2 Safety management entities

Within the Railway Law mentioned above, a state railway transport institution means a railway administration or a railway sub-administration, considering as a role of safety authority. A railway sub-administration is a transport entity in primary level who independently takes charge of railway transport production, namely passenger or freight transit. Consequently, it deserved to act as safety management entities to carry out principles implied in safety legislation.

A common transport management system is shown in Fig 2, it can be seen that such system emphasizes the responsibility in the context of role division. In regards to safety responsibility, this system proposes four levels to assign tasks and put safety policy into practice:

- Supervision level: Safety supervision office is in charge of executing enacted safety production policy, task, regulation and indication, monitoring their actual performance and

investigating the incidents and controversial accidents located in sub-administration.

- Strategy level: Sub-administration draws up annual guidance on safety tasks and figures out the local regulation as interpretation in accordance with superior principles. In addition, they have to fix specific methods of installing, using and maintaining safety equipments in order to check the fundamental safety construction in respective districts.
- Execution level: each station district has to accomplish assigned tasks and report to superior department for approval. Besides that, they will be in charge of investigating and analyzing normal accident within the district themselves.
- Implementation level: the correlative teams or staff must work out concrete safety target and assurance measures, and then issue these indicators to the corresponding teams or staff.

It should be noted here, that currently breakthrough change has happened in this system. A newly mode of separation of infrastructure from operation (SIO), which facilitates classification management and benefits to build a state railway network company, and independent powerful passenger or freight traffic companies, will reasonably settle the institutional drawback, and avoid responsibility conflict within such systems. The combination of the both tends to the theme of assuring transport safety.

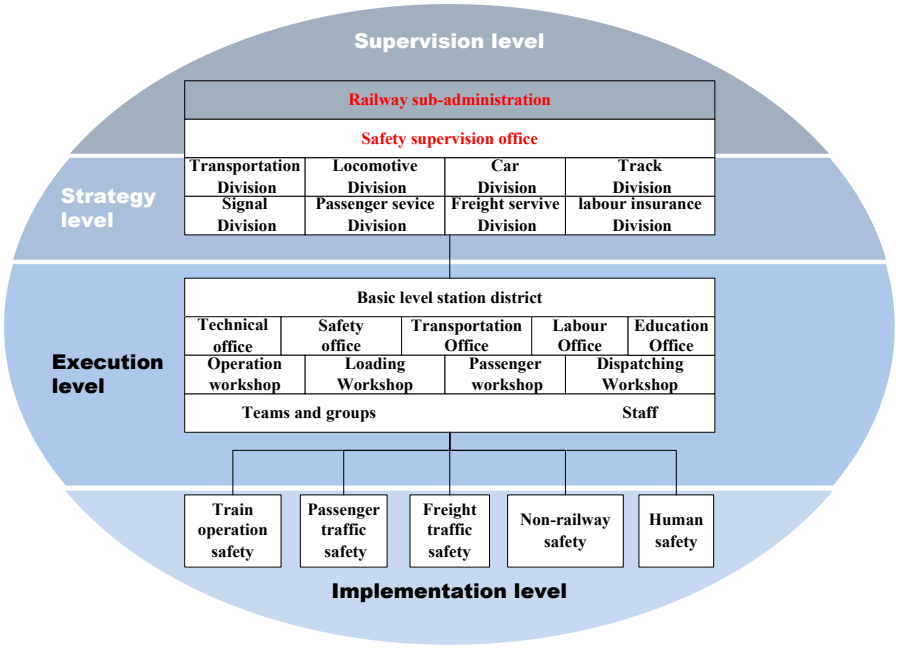

Figure 2. Safety management system of sub-administration

2.3 Achievement in operational management

In terms of system operation indicator, some historical statistic data derived from Ministry of Railway (MOR) can explain what China has achieved on railway transportation during last five years[6]. According to Table 1, the volume gross of both passenger and freight is continually growing yearly, on the contrary, the railway causalities caused by non-railway factors, which directly mirrors the effects of safe operational management, have shown a declining trend. What is particularly worth mentioning here is the period of last five years is the stage from which China strived to build high speed railway network and have made great contribution to national economy and international high-speed railway development. The result positively approves the current safety managing mechanism is highly effective especially in the demand of great-leap-forward development in China.

Table 1 Annual passenger and freight transport volumes and accident report

Year	Annual Passenger dispatched volume(million person)	Annual passenger turnover volume(billion person)	Annual freight dispatched volume(million ton)	Annual freight turnover volume(billion ton kilometer)	Accident Report	railway casualties by non-railway factors
2009	1524.5	787.9	3320.4	2494.3	No heavy accident	-20.1%
2008	1461.3	777.9	3259.3	2481.7	1extraordinarily serious accidents, 3 heavy accidents	-30.4%
2007	1317.0	721.7	3144.7	2395.3	4 heavy accident	-43.8%
2006	1256.3	662.2	2870.9	2171.4	4 heavy accident	-20.1%
2005	1155.8	606.1	2683.5	2053.5	5 heavy accidents	--

2.4 Evolution of principles

In relation to China railway development in the last half century, the most distinct performance in safety management is the complexity. New development features in railway construction, as introduced in section 1, have resulted in an evolution of safety managing principles, which we can summarize as below:

- Initiated by regulation-by-men principles: Because of uneven developed management entities equipped with technical capabilities, It is hard to impose uniformity on the implementation of the safety policies. Regulation-by-men means reckless of human divergence, as long as regulation elaborated roles and responsibilities, the safety policies and guidance can be conveyed level-wisely. That is the reason that most of regulation clauses are stated what one have to do, rather than how to do. However, the specific way-to-do still depends on the specific capability under specific circumstance.
- Enriched regulation-by-men via supplement and update in terms of new technologies and operation. For instance, ATP system has to enhance the capacity of receiving both cab signal and digital signal to meet large data transferring, and microcomputer interlocking replaces the obsolete ail-relay interlocking. Such substitution contributes to enhancing execution of regulations supposed to be carried out by men, in this situation, the traditional regulation-by-men can still work well because the supplement and update for regulation can still keep pace with the scope of unsafe events emerged, so a compulsory execution according to these regulation still satisfies the safety targets.
- Risk-based safety management and assessment framework is widely being popularized. A systematic consideration is necessary to handle such complexity: One hand, the unpredictable fault modes within the functional-integrated software expands as its possible state space is generated; however, effective detecting and control methods are far behind increasingly perfect software developing ideas. On the other hand, lack of experiences on operation and maintenance under extreme condition, such as super speed running, makes the existing management techniques more or less incompatible with newly applied technologies, which itself might become unsafe factors.

However, as the system is concerned with thousands of lives, we cannot just burn the existing

regulations and laws and start a revolution to build new order. Introducing risk-based principle to the existing regulations and reorganizing safety management activities are much wiser options, which will be necessarily highlighted in the future development.

3 A SMS framework in China

3.1 Architecture

In this section, a Safety Management Architecture for China Railway is suggested, shown in Fig 3. Five common elements are involved in such risk-based SMS. Organization Fundamentals and Process Fundamentals compose the basic requirements for the duty holders, who should clearly define the safety responsibilities of all relevant positions, and establish proper safety reporting mechanism. These duty holders should also maintain scientific process for planning, evaluating, recording and reviewing safety related work to make hazards traceable. On this basis, a whole set of hazard identification and analysis technologies can be introduced as specific measures to instantiate the process in the bottom. As the consequences of these hazards are quantified in the concept of risks, methodologies of assessing and controlling risks will be brought into the specific product and application development, meanwhile, relevant quality management and process assurance will be implemented with the evidences supported by safety regulations. But above all these things, a unified and unambiguous safety principle will give an invisible and formative guidance on these activities above during each step of system life cycle.

Through these five common elements, the techniques for Risk Assessment and Risk Control are well developed and universal interrelated. However, the Organization, Process and Safety Principle are closely related with national circumstances and should embody the continuity of policy. In Chinese railway industry, the regulation and laws, we mentioned in last chapter, have perfectly defined the responsibilities of all the participated roles and standardized most procedures for practitioners, even supervisors. It cannot be denied that most of these specific clauses are still applicable today and should be carried forward. In order to insuring the continuity of safety management and adopt the technology development at the same time, we consider it is necessary to plug Risk Based PDCA Principle into existing safety laws and regulations for Organization and Process aspects, and define Safety Principle under our circumstance. In this way, to guarantee systematic safety doesn't depend on those measures approved by men but the indicators assigned by risk allocation.

Figure 3. A suggested SMS in China railway

3.2 PDCA cycle

Any process involved in SMS framework should be applied to each of the lifecycle phrases. It may be that specific adaption or expansion of a duty holder's overall generic SMS may be required to address specific issues relating to the various lifecycle phrases [5].

For example the safety policy commitments may contain specific commitments for each lifecycle phase and these should be cascaded so that the SMS framework sufficiently addresses them, however, regardless of any specific commitments the Safety Policy and the resulting SMS should be appropriately address each of the lifecycle phrases.

Table 2 shows the mapping between necessary elements in SMS framework with Deming cycle. The quality of an SMS is typically assessed through audits, which are based on a control and monitoring Loop (for example, deming cycle). By going around such loop, the completeness of the loop is investigated can be quantified numerically or qualitatively. Therefore, if for every activity within an SMS there is a policy or a plan related to safety, evidence that it has been implemented and checked by measurement of performance is required .Also it needs to be included that the results of these checks or measurement are followed up by the management.

Table 2. PDCA cycle of SMS elements

Deming	Safety management System	
Plan	Nature and scope of duty holder's business Safety policy	
	Risk management	Risk identificaition
		Risk control
		Safety assurance
Do	Organizational structure and responsibilities	
	Competence, Training and Fitness	
Check	Incident and accident reporting and learning	
	Emergency Management	
	Safety Communication and Information Integrity	
Act	Monitoring ,Auditing, Corrective measures and Annual reports	

3.3 Safety Principle for Chinese Railway

In SMS, safety principle is the criteria to judge 'How safe is safe enough'. It is largely affected by the economic level, society cultural, legal framework and technology development of a country. Therefore, each country chose different safety principle. The most popular three safety principles in the world are ALARP used in UK, GAMAB used in France and MEM used in Germany. GAMAB principle and MEM principle give out two more specific risk acceptance criteria and it is more convenient to proceed. ALARP principle seems much more obscure and weak-binding. However, it provides a friendly policy for applying new techniques on the other hand. Moreover, ALARP presents the procedure of risk assessment and risk control, and more closely integrated with system development.

Nowadays, the bottleneck of Chinese railway is the capacity of passenger delivery and freight turnover lags behind the development of economy, accordingly, lots of new lines with new techniques introduced are under construction to cope with this contradiction. In this regard, ALARP principle is more appropriate for current railway technology development. Besides, in

legal aspect, China is a nation belonging to 'statute law' system [7] as France and Germany, which requires the law clauses should be abstractive and principled [8]. In society aspect, Chinese social supervision mechanism is not perfect, so that it cannot just rely on companies to consciously improve system safety. Furthermore, in China, the trains, fundamentals and managerial authorities of all railway lines are owned by the state. Railway accidents are not just corporate behavior, and directly affect the image of the government. Therefore, safety principle should be objective and clear, and easy to inspect. Obviously, ALARP is not satisfactory in this regard. So, we suggest amending ALARP with GAMAB principle. 'Risk Acceptable Line' of ALARP should be defined by the authorities depending on the national statistics. All duty holders, including companies and railway operators should prove to the government that remaining risk is below this line and they have do their best to reduce risk.

4 Conclusion

According to the legislation basis of railway safety production and safety management entities in China, it is feasible to establish a SMS framework in China railway construction in consideration of insuring the continuity of safety management and adopting the safety assessing technology development at the same time. To drive an integration of regulation-by-men system with risk control methodology needs continual review and evaluation of effects brought back from executive entities. Above all, a rectification of strategy, such as safety principles, will essentially improve an internal circumstance for China railway safety management.

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