Abstract: Engineering construction has major influence on the permafrost environment. This paper analyzes the interaction between engineering construction and permafrost environment along the Chaida'er-Muli Railway (simply, CMR) based on the press-state-response (PSR) framework. The permafrost environmental system is divided into three subsystems, consisting of permafrost thermal stability, proneness to the freeze-thawing erosion and permafrost ecological fragility. Each subsystem considers its most important influencing factors. Catastrophe Progression Method (CPM) is applied to calculate the current environment condition along the railway. The result indicates that: (1) as far as the thermal stability is concerned, most sections along the CMR are mainly concentrated in rank Ⅲ (fair situation), and a few in Ⅱ (good situation) and Ⅳ (bad situation), respectively; (2) for the proneness to the freeze-thawing erosion, the entire railway route falls largely in rank Ⅱ (good situation); (3) along the CMR, the ecological fragility of the permafrost environment is in rank Ⅱ (good situation), or slightly fragile; (4) overall, the permafrost environments along the CMR are in rank Ⅲ (fair situation) or Ⅱ condition (good situation). In general, the permafrost environment along the CMR is fair. It is mainly because a series of active measures of protecting permafrost were taken for stabilizing the CMR foundation soils. On the other hand, we should try our best to minimize the influences that engineering activities have exerted on ecology and environment, on the other hand, the positive measures have made improvements to prevent the permafrost environment from deterioration.

Keywords: Permafrost environment; Press-state-response framework; Catastrophe theory; Chaida'er-Mu Railway; Environmental impact

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Introduction

Permafrost is a special geological material due to its thaw-sensitivity property. Even if the permafrost suffers from slight disturbance, the permafrost environment will change significantly. It is due to that the permafrost environment is influenced beyond its bearing capability. The change of permafrost environment does not only include the change of permafrost itself, but also includes the change of surrounding natural environment. Especially, in the course of socioeconomic development, exploration and exploitation of natural resources are bound to induce change in and imbalance for the permafrost environment (Jin et al. 2008; Wu et al. 2014). Permafrost environment could be vulnerable to external disturbances such as climate change and human activities (Jin et al. 2008; Lin et al. 2011; Sheng et al. 2015). In particular, engineering construction and subsequent operation could substantially influence the permafrost environment. Due to the ever increasing economic development and exploitations in permafrost regions, significant environmental hazards and issues have been reported regarding large linear projects, such as the Alaska Pipeline, Highway and Railway, the Norman Wells Pipeline, the Trans-Siberia Railway, and the Qinghai-Tibet Highway and Railway (He et al. 2011; Hildebrand 1983; Peretrukhin and Potaueva 1983; Burgess et al. 1993; Wu et al., 2001). These investigations show that engineering construction has severe influence on permafrost environment (Li et al. 2012; Peng et al. 2015; Yang et al. 2010; Wu et al. 2015).

It becomes more and more important to evaluate the quality of the permafrost environmental to face the severe environmental issues. This is because the permafrost environment assessment could provide scientific basis and management countermeasure for engineering construction. Thus, numerous scholars have paid more attention to the study of permafrost environment assessment. For the permafrost environment assessment, a large number of researchers have focused on the qualitative assessment of permafrost stability and ground surface sensitivity, and the thermodynamic function model based on environment and landscape complexity in permafrost regions (Harris 1983; Dunayeva et al. 1983; Greshchev 1983). Moreover, the correlation study has been represented by comprehensive qualitative evaluating-model of permafrost environmental change under engineering activities (Wu et al. 2002). Cao et al. (2011) employed a new method, the Catastrophe Progression Method, to quantitatively estimate the permafrost environment of Muli mining area in Qinghai-Tibet Plateau, China. At present, the permafrost environment assessment mainly analyzes how human engineering activities have affected the active layer in permafrost regions and its environment from the perspective of engineering geology. There are relatively a few ecological analyses on permafrost environment. Moreover, there are more qualitative evaluations for assessing the permafrost environment. Permafrost environment is one of the important components of plateau ecological environment, and the environment could be fragile in permafrost areas on the Qinghai-Tibet Plateau. Especially, the permafrost environment will become more vulnerable under the effect of human activities and linear engineering construction.

1 Study Area

The Chaidaer-Muli Railway (CMR) is the first local railway with a total length of 142 km in northeastern Qinghai Province, China. The CMR starts from Chaidaer County town (100°25’55”E, 37°35’40”N) and ends in Muli Country town (99°11’00”E, 38°08’38”N). Figure 1 gives the geographical location of the CMR and the permafrost zones along CMR based on the mean annual ground temperatures. Topographically, it passes through the Datong River valley, the Datong Mountains and the front edge of the Tuolai Mountains in the central-eastern Qilian Mountains. The railway runs from Southeast to Northwest. The elevations of this region range from 3600 m to 4100 m a.s.l. The annual average air-temperature varies from about -2.4°C to -5.8°C. According to the meteorological data, the minimum air temperature is -40°C and the maximum air temperature is 17°C. There is moderate rain and snowfall, and swamps as well as marshes are both well developed. The multiyear average annual