MODELING OF RECOVERY RATE OF INFRASTRUCTURE SYSTEM USING THE COVARIATE BASED MODEL

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The resilience of infrastructure systems is of significant concern in the case of disruptive events such as earthquakes. Resilience is often described as a function of robustness and recovery rate. Robustness defines the ability of a system to resist the initial adverse effects of a disruptive event and the recovery rate shows the rate or speed at which a system is able to return to an appropriate operability following the disruption (McDaniels et al., 2008; Barker and Baroud, 2014). In order to have an effective risk management plan in the case of natural disaster, it is very important to have an accurate estimation of the recovery rate of the infrastructure as well as knowing the impact of such natural disaster (consequence of the disruptive event). Historical data play an important role in the estimation of the recovery rate of a disruptive event as they reflect the conditions that the recovery crew and different components of infrastructure has to experience during the recovery process.

Historical recovery data are generally non-homogeneous. This can be due to differences in disruptive events, operational and environmental conditions, requirements and available resources, recovery procedures, etc. Hence, the statistical method which is used to analyse such data should be able to model such influence factors. This paper addresses the analysis of historical recovery data using the covariate based statistical models (CBSMs). In these models all influence factors on recovery rate can be modelled as covariates. The CBSMs can be broadly classified into two main groups: the parametric model and the non- parametric model. In the parametric method, the lifetime of a system is assumed to have a specific distribution such as lognormal, but in the non-parametric method no specified distribution is assumed for the lifetime of a system. In general when there is no clear theoretical reason for positing a particular recovery rate, the non- parametric model may be preferred over parametric models.

Recently, the applications of CBSMs in order to estimate the repair rate have been addressed in reliability engineering (Barabadi et al., 2011; Barker and Baroud, 2014; Gao et al., 2010). For example, Gao et al. (2010) developed the concept of proportional repair model (PRM), and later Barabadi et al. (2011) showed the application of PRM to model the effect of time-dependent and time-independent covariates on repair rate of the equipment. In PRM the repair rate of a component is the product of a baseline repair rate $\mu_0(t)$, and a functional term $\psi(z\beta)$ describes how the repair rate changes as a function of influential covariates. The PRM is described as follows (Gao et al., 2010):

$$\mu(t,z) = \mu_0(t)\psi(z\beta) \tag{1}$$

where z is a row vector consisting of the covariates, and β is a column vector consisting of the regression parameters. The baseline repair rate is the repair rate under the standard conditions, $z=0$, and requires $\psi(z\beta)=1$, when there is no influence of covariates on the repair time. The shape of the baseline repair rate and the regression coefficients for the covariates may be estimated from historical data or by using input from experts. Different parameterization forms of $\psi(z\beta)$ can be used, such as the log linear form, $\psi(z,\beta)=e^{\beta^t z}$, the linear form, $\psi(z,\beta)=1+\beta^t z$, and the logistic, $\psi(z,\beta)=\log(1+\beta^t z)$. The most important step in historical data analysis using the CBSMs is selecting the appropriate model as if the historical data does not follow the applied model, the result of analyis may be misleading. The suitable statistical approach must be selected based on the effect of covariates on the repair process (Kumar and Westberg, 1997; Barabadi et al., 2014). This study will show how selecting the statistical approach can affect the result of the estimated recovery rate of infrastructures, later it will propose a guideline for selecting the appropriate model for specific data set. Finally, the application of the guideline will be demonstrated by a case study.

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