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Analysis of Safe and Effective Next-Generation Rail Signalling Systems using a FTA-SAN Approach

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Moving Block (MB) and Virtual Coupling (VC) rail signalling will change current train operation paradigm by migrating vital equipment from trackside to onboard to reduce train separation and maintenance costs. Their actual deployment is however constrained by the industry's need to identify configurations of MB and VC signalling equipment which can effectively guarantee safe train movements even under degraded operational conditions involving component faults. In this paper, we analyse the effectivity of MB and VC in safely supervising train separation under nominal and degraded conditions by using an innovative approach which combines Fault Tree Analysis (FTA) and Stochastic Activity Network (SAN). A FTA model of unsafe train movement is defined for both MB and VC capturing functional interactions and cause-effect relations among the different signalling components. The FTA is then used as a basis to apportion signalling component failure rates needed to feed the SAN model. Effective MB and VC train supervision is analysed by means of SAN-based simulations in the specific scenario of an error in the Train Position Reporting (TPR) for five rail market segments featuring different traffic characteristics, namely high-speed, mainline, regional, urban and freight. Results show that the overall approach can support infrastructure managers, railway undertakings, and rail system suppliers in investigating effectiveness of MB and VC in safely supervising train movements in scenarios involving different types of degraded conditions and failure events. The proposed method can hence support the railway industry in identifying effective and safe design configurations of next-generation rail signalling systems.

Keywords
Moving Block, Virtual Coupling, Safety, Performance, Stochastic Activity Network