Chapter 4  
Reliability Model for AGV

4.1 Summary

The Material Handling System (MHS) in a manufacturing setting plays an important role in the performance of the entire system. Inadequately designed MHSs can interfere with the overall performance of the manufacturing system and lead to substantial losses in productivity and competitiveness, and to unacceptably long lead times. Among the advanced technologies available for MHSs, Automated Guided Vehicles (AGVs) have found increasing applications because of their capability to transport a variety of part types from point to point without human intervention.

Today’s automated MHSs are technologically advanced and increasingly complex. Uncertainty is an inevitable consequence of the complexities generated by technological advancements. Jain et al. (2013) show that most of the automated manufacturing studies have used single-item measures. They argue that single-item measures are appropriate for relatively simple manufacturing systems. As the different dimensions of automated MHSs are complex in nature, single-item measures are inappropriate. Choosing adequate and relevant performance measures is critical in accurately analyzing MHSs (Beamon, 1998). A company also needs to address uncertainties in the manufacturing system to survive and compete in such an uncertain environment (Jain et al. 2013).

AGVs are the most flexible means for transporting pieces among workstations in an automated manufacturing system. An AGV is a driverless and programmed vehicle used to transfer the load from one part of a manufacturing facility to another part (Maniya and Bhatt, 2011). Maxwell and Muckstadt (1982) first recognized the importance of AGV-based MHS design. They developed an optimization model that minimized the total travel time and determined the maximum number of AGVs needed to efficiently transfer material from one shop to another. AGVs increase efficiency, reduce costs, and improve flexibility by automating an MHS. Time-based performance measures are often used to evaluate MHSs with AGVs. However, moving materials from one part of the manufacturing floor to another part utilize time and incur costs. In this study, we consider both time and cost measures in an optimization model and evaluate an MHS with AGVs.
The use of AGVs increases flexibility and has a significant impact on the overall performance and reliability of MHSs (Sarker and Gurav, 2005). As AGVs become larger and more complex, the traditional design requires more attention to issues such as control, cost, time, reliability, flexibility, etc. A number of different MHS design and evaluation methods (e.g., simulation, optimization, and the genetic algorithm) have been proposed in the literature. Simulation is an acceptable method for analyzing manufacturing systems. However, simulation is often challenging and time consuming (Law and Kelton, 2000; Kuo et al., 2007), particularly, when it is used for modeling complex manufacturing systems such as MHSs with AGVs.

The problem of scheduling AGVs in an automated MHS has been studied extensively. Abdelmaguid et al. (2004) addressed the problem of simultaneous scheduling of machines and AGVs with the objective of minimizing the makespan. This problem is composed of two interrelated decision problems: the scheduling of machines, and the scheduling of AGVs. They showed that each problem is an NP-complete problem and a simultaneous consideration of the two problems results in a more complicated NP-complete problem. They proposed a hybrid genetic-algorithm/heuristic coding scheme to solve the problem. Deroussi et al. (2008) also studied this problem and proposed a solution based on vehicles rather than machines. Each solution was evaluated using a discrete event approach. Gnanavel Babu et al. (2010) studied this problem further and proposed a meta-heuristic differential evolution algorithm for solving it. They introduced an iterative algorithm that anticipated the complete set of flow requirements for a given machine schedule and made vehicle assignments accordingly. Le-Anh and De Koster (2006) have compiled a comprehensive review of the AGV design and control models and methods in the literature.

Farling et al. (2008) used a simulation model to compare the performance of three AGV configurations under a variety of experimental conditions. They showed that system size, load/unload time, and machine failure rate factors have significant impacts on the operation and reliability of MHSs. Smith (1993) defined reliability as the probability that an item will perform a required function, under stated conditions, for a specific period of time. A reliability measure is a metric for quantifying this probability. A number of different reliability measures (i.e., availability, unavailability, failure rate, and mean time between failures) have been proposed in the literature. For degradable systems, such as MHSs, the performance of the system during a specific period of time can be described by different levels of performance as a function of machine failures (Beamon, 1998). Miriyala and Viswanadham (1989) developed several measures and algorithms for evaluating part-based reliability and system-based reliability for automated MHSs. Beamon (1995) proposed an analytical model for designing guide paths for automated MHSs as a function of reliability and quantified the reliability of the handling components.

In order to ensure an acceptable service level for each machine in each shop, we adopt and further extend the concept of reliability proposed by Ball and Lin (1993) in the model. We define reliability as the probability that the system is operational until time $t$. A failure is when a machine in a shop breaks down.