Efficient methods for simulating operators performing part handling tasks in manufacturing plants are needed. The simulation of part handling motions is an important step towards the implementation of virtual manufacturing for the purpose of improving worker productivity and reducing injuries in the workplace. However, industrial assembly tasks are often complex and involve multiple interactions between workers and their environment. The purpose of this paper is to present a series of industrial simulations using the Human Motion Simulation Framework developed at the University of Michigan. Three automotive assembly operations spanning scenarios, such as small and large parts, tool use, walking, re-grasping, reaching inside a vehicle, etc., were selected. A conceptual model for describing relationships among task objectives, the environment, parts and tools, as well as worker variability, work methods, motion patterns, and musculoskeletal disorder (MSD) risks is proposed as a structure for conducting the case studies. The conceptual model is implemented using simulation strategies and the HUMOSIM Framework. Analyses demonstrate that the HUMOSIM Framework provides improvements on simulation capabilities over the built-in Jack functionality, such as the prediction of force-exertion posture and stepping motions. But knowledge gaps are also identified for part handling simulations, in particular the prediction of grasping and re-grasping. Methods for integrating part assembly paths generated by other simulation software are also needed.