Chapter 5

A Framework for the Modelling and Optimisation of a Lean Assembly System Design with Multiple Objectives

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ABSTRACT

The newest assembly system is lean assembly, which is specifically designed to respond quickly and economically to the fluctuating nature of the market demands. Successful designs for these systems must be capable of satisfying the strategic objectives of a management in manufacturing company. An example of such systems is the so-called walking worker assembly line WWAL, in which each cross-trained worker travels along the line to carry out all tasks required to complete a job. Design approaches for this system have not been investigated in depth both of significant role in manual assembly process design; productivity and ergonomics. Therefore these approaches have had a limited success in actual applications. This chapter presents an innovative and integrated framework which offers significant potential improvement for productivity and ergonomics requirements in WWAL design. It establishes a systematic approach clearly demonstrating the implementation of a developed framework based on the simultaneous application of mathematical and meta-heuristic techniques.

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1. **INTRODUCTION**

The newest assembly system is lean system, which is specifically designed to respond quickly and economically to the fluctuating nature of the market demands (Katayama & Bennett, 1996). One of the cornerstones of lean assembly is the advantage of work-force flexibility in systems where the workers are able to switch tasks rapidly enabling the line to respond quickly to changing production demands. This results in improved system efficiency in the form of higher throughput, less work in process (WIP), and shorter cycle times without significant additional investment in equipment and labour (Downey, 1992). One advantageous form of flexible force-work is the use of cross-trained workers to perform all assembly operations required on a product under manufacture. As such, they are capable of shifting their capacity to where it is needed (Hopp et al., 2004). An example of such systems is the so-called walking worker assembly line (WWAL), in which each cross-trained worker walks down the line carrying out each assembly task at each workstation as scheduled. Thereby, each walking worker completes the assembly of a product in its entirety from start to end. Figure 1 illustrates the concept of WWAL, where a walking worker completes the product assembly process at the last workstation and then moves back to the first workstation to begin the assembly of a new product. At most workstations the nature of the assembly process in manual assembly systems requires manual tasks performed by the worker. Therefore, the optimal design should consider both productivity and ergonomics aspects of the system. To deal with such optimisation problems, robust modelling and optimisation techniques are required, particularly when human-centric-manufacturing process relationships in the problem increase, as in manual assembly operations in WWAL. As a result of the exhaustive literature review in research of Al-Zuheri (2013), it has become clear currently there are no design frameworks which include the required techniques for a demonstration of this. Therefore, this chapter describes the development of a novel framework, developed to optimise designs of WWAL. To clearly demonstrate the development of the framework approach step by step, this chapter proceeds as follows: firstly, existing research about WWAL provides no complete experimental or empirical modelling or optimisation techniques in relation to overall system performance. Rather, a massive body of literature has focused on modelling and optimisation in order to find solutions for many fixed-worker (FWAL) design problems in traditional assembly lines. Therefore, these are reviewed as the theoretical foundation for a new approach. On this basis, the capabilities and limitations of the techniques proposed in this literature are analysed. As a result, an appropriate framework mechanism is proposed for comprehensively addressing all essential characteristics of an efficient design of WWAL which profoundly impacts productivity and ergonomics. Based on such a mechanism, a methodically structured framework is developed to achieve comprehensiveness and optimality in

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*Figure 1. Layout of walking worker line (Wang et al., 2005)*