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Invited Review

Loop based facility planning and material handling

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Abstract

A sizeable proportion of manufacturing expenses can be attributed to facility layout and material handling. Facility layout decisions involve designing the arrangement of elements in manufacturing systems. Among the most critical material handling decisions in this area are the arrangement and design of material flow patterns. This survey article reviews loop based facility planning and material handling decisions for trip based material handling equipment with an emphasis on unit load automated guided vehicles. The article examines issues related with facility design, material handling design, and fleet sizing and operating.

Keywords: Layout; Facility planning; Material handling; Automated guided vehicles; Flexible manufacturing

1. Introduction

Facility layout decisions involve designing the arrangement of elements in manufacturing systems. Among the most critical decisions in this area are the arrangement of departments, production units, manufacturing cells, centers, storage areas, etc. As pointed out by Apple (1977) it is crucial to incorporate material handling decisions in layout design. Tompkins et al. (1996) estimate that between 20% and 50% of operating expenses in manufacturing can be attributed to facility planning and material handling. Thus any cost saving in this area can contribute to the overall efficiency of the production system.

There exists an extensive literature on such problems (see, e.g., Francis et al., 1992; Ganesharajah et al., 1998). In this article we review the layout and material handling decisions in the context of *loop* based material flow systems. The loop layout is one of the four well known general types of design used in production systems (Apple, 1977). It lends itself to both product and production simplicity (Afentakis, 1989). In a basic layout design, each cell is represented by a rectilinear, but not necessarily convex polygon.

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The set of fully packed adjacent polygons is known as a *block layout*. A block layout is usually integrated with a material flow system which is defined in terms of material handling equipment, configuration and directions of the material handling network, and the number and locations of pickup (P) and delivery (D) stations (Tanchoco and Sinriech, 1992). Here we mainly discuss trip based (Bozer et al., 1994) material handling equipment with an emphasis on unit load automated guided vehicles (AGVs). AGVs are preferred to stationary material handling robots for their mobility and to conveyors for their flexibility.

In Fig. 1, four common material handling networks are superimposed on a block layout. Fig. 1a corresponds to the conventional configuration (Maxwell and Muckstadt, 1982). It is a unidirectional network covering all the edges of the block layout. To understand the underlying layout of Fig. 1a and b one must ignore the arrowheads. We symbolically refer to each of the polygons of the block layout as a manufacturing cell. A conventional configuration may result in substantial vehicle blocking and is more difficult to operate and control. A complex and expensive software is required for the operation of such systems (Sinriech and Tanchoco, 1992a,b). The operational issues can be classified as: (a) Dispatching: when a station is calling for a vehicle, determine which of the several idle vehicles should serve it. When several stations are calling, decide where to assign the single idle vehicle. (b) Vehicle routing: determine the best origin-destination route. (c) Traffic management: if more than one vehicle arrive at an intersection, select the vehicle that has right of way. The unidirectional streamlined loop network of Fig. 1b is often preferred for its simplicity (Tanchoco and Sinriech, 1992). It is a loop covering at least one edge of each manufacturing cell. Another example of a simplified system is the tandem configuration (TC) (Fig. 1c) which decomposes the flow pattern into several bidirectional loops each served by a single vehicle. Two loops are connected to each other either by a transfer station or by a small conveyor section (Bozer and Srinivasan, 1989). This eliminates blocking at the expense of transshipment between the segments. Note that in Fig. 1c since the loops are close to each others, there is no need for a conveyor but only for a transfer station. If the loops are disjoint, a piece of conveyor is installed to connect them. Finally, a segmented loop topology is depicted in Fig. 1d (Sinriech et al., 1996). It is a bidirectional loop covering all cells and partitioned into nonoverlapping segments. Each segment is assigned to a single vehicle or to some stationary material handling equipment. The segmented flow pattern is not necessarily connected.

This survey concentrates on loop based configurations, including segmented loop topology and tandem configurations. Readers interested in conventional configurations are referred to Sun and Tchernev (1996) for a comprehensive review. In all the models where the layout of the departments is known, with the exception of the tandem configuration, the AGVs are not supposed to cross the cells and work centers. The material handling aisles are constructed on the edges separating the manufacturing cells.

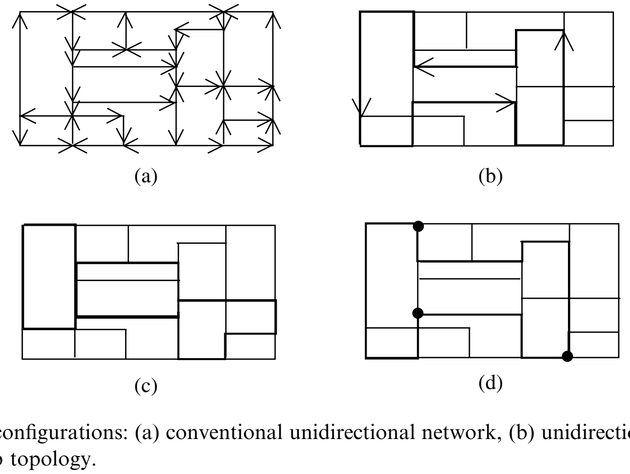

Fig. 1. Four basic material flow configurations: (a) conventional unidirectional network, (b) unidirectional loop network, (c) tandem configuration, (d) segmented loop topology.