Chapter 2.11
Decision Making and Support Tools for Design of Machining Systems

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INTRODUCTION

The *design of manufacturing systems* is a wide open area for development and application of decision making and decision support technologies. This domain is characterized by the necessity to combine the standard decision making methods, sophisticated operational research techniques, and some specific rules based on expert knowledge to take into account principal technological constraints and criteria.

A promising trend in this area deals with the development of integrated software tools (Brown, 2004; Grieves, 2005; Stark, 2005). Their main idea consists in integrating product and manufacturing data into a common database. This enables product designers to consider the manufacturing processes constraints at the early product design stage. At the same time, all data of product design should be used directly for optimizing the corresponding manufacturing system. That is why the core of these software tools is a powerful extendable database, supported by a user friendly software environment. This database normally contains digital models of product and processes. In order to find an optimal manufacturing system configuration, a set of advanced decision making and decision support methods are used for data processing.

In this work we present the main principles and ideas of decision making by the example of decision and support soluton for machining systems used for mass production. The used approach is based on several techniques:

- Powerful database of standard solutions and
  efficient mecanisms to search the existing elements
- Expert system to choose better solutions from database;
- Line balancing model based on shortest path
  approach;
- Set of problem oriented rules; and
- User friendly software environment.

These techniques are combined in the decision support software tool for optimal process planning, line balancing, and equipment selection for optimal design of a transfer machine with rotary or mobile table.

BACKGROUND

The studing of line design problems began by considering the simple *assembly line balancing problem* (SALBP) (Baybars, 1986; Scholl & Klein, 1998). The SALBP consists in assigning a set of operations to identical consecutive stations minimizing the number of stations required, subject to *precedence constraints* between operations and *cycle time* constraints. Many exact and heuristic approaches for SALBP were suggested in literature: lagrange relaxation techniques (Aghezzaf & Artiba, 1995), branch and bound algorithms (van Assche & Herroelen, 1998; Ugurdag, Papachristou, & Rachamadugu, 1997; Scholl & Klein, 1998), and heuristics and meta-heuristics (Arcus, 1966; Helgeson & Birnie, 1961; Rekiek, De Lit, Pellichero, L'Eglise, Fouda, Falkenauer *et al*., 2001). This list is not exhaustive. A state-of-the-art can be found in (Baybars, 1986; Becker & Scholl, 2006; Erel & Sarin, 1998; Ghosh & Gagnon, 1989; Rekiek, Dolgui, Delchambre, & Bratcu, 2002).

The problem where line balancing is combined with equipment selection is often called *simple assembly line design problem* (SALDP) (Baybars, 1986; Becker & Scholl, 2006) or *single-product assembly system design problem* (SPASDP) (Gadidov & Wilhelm, 2000). SALDP considers the "high-level" logical layout design with equipment selection (one per station) from a set of alternatives. There are several equipment alternatives for each operation, and often a particular piece of equipment is efficient for some operations, but not for others (Bukchin & Tzur, 2000; Bukchin & Rubinovich, 2003). There is a given set of equipment types; each type is associated with a specific cost. The equipment cost is assumed to include the purchasing and operational cost. The duration of an operation depends on the equipment selected. An operation can be performed at any station, provided that the equipment selected for this station is appropriate and that precedence relations are satisfied. The total station time should not exceed the predetermined cycle time. The problem consists of selecting equipment and assigning operations to each station. The objective is to minimize the total equipment cost.

The *balancing of transfer lines and machines* (Dolgui, Guschinsky, & Levin, 2000) deals with grouping operations into a number of blocks (sets of operations performed by a spindle head) and assigning these blocks to stations. Each block requires a piece of equipment (a multi-spindle head), which incurs a purchase cost. Therefore, it is necessary to minimize both the number of stations and the number of blocks. To do it, all possible operations assignments to blocks and stations must be considered; otherwise the optimality of a solution cannot be guaranteed. The set of alternative blocks is not known in advance and the parameters of a block depend on the set of operations assigned to it. Therefore, the bal-