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Selection of assembly lines feeding policies based on parts features

Antonio C. Caputo*. Pacifico M. Pelagagge**
Paolo Salini**

**Department of Engineering, University Roma Tre, Roma, Italy*
(email: acaputo@uniroma3.it).
** *Department of Industrial Engineering, Information and Economics, University of L'Aquila, Italy.*
(email: pacifico.pelagagge@univaq.it; paolo.salini@univaq.it).

Abstract: This paper explores the impact of parts features, i.e. unit size and cost, on the total delivery cost of materials to assembly lines workstations, considered as a criterion to directly select the feeding method to be adopted for each part type. After building cost models for different materials feeding processes (kitting, line storage, and just in time delivery) a parametric analysis is carried out in order to understand whether economic breakeven points exist among available feeding alternatives on the basis of the values assumed by relevant attributes of parts. This allows to map areas where each feeding policy is more convenient and also allows a quick method to choose the best feeding policy for each part on an economic basis.

Keywords: Material handling error, kitting, assembly line, parts feeding, line storage, just in time.

1. INTRODUCTION

To supply parts at the work stations is one of the main problems to be faced by assembly lines designers and managers. Several methods are available and each one is characterized by distinct advantages and drawbacks (Caputo and Pelagagge, 2011; Hanson and Brolin, 2012; Hua and Johnson, 2010). Parts kitting is a frequently adopted method to deliver parts to assembly lines. In a kitting policy (Brynzèr and Johansson 1995; Bozer and McGinnis 1992, Caputo et al., 2015a) all parts required to assemble one unit of the end product are placed into one or more kit containers. Kits are prepared in a stockroom and delivered to the assembly line, either at the start of the line (travelling kit concept) or to specific workstations (stationary kits), according to the production schedule. As an alternative to kitting continuous supply policies are also widespread, where each different part number is supplied in an individual container to the assembly line (Caputo et al., 2015b). This allows a stock of each needed part type to be continuously held at the workstation. Small sized containers may be moved in Just In Time (JIT) fashion from a supermarket storage area by tugger trains performing milk runs among workstations. Otherwise larger containers holding bulk quantities are simply stored along the line and periodically replenished (Line-Storage, LS). Each policy presents pros and cons, so it is impossible to generally state that a feeding policy is clearly superior to the others. Cost issues, case-specific requirements and constraints may favor one option over the others in an assembly system. Therefore, choosing the best parts feeding method is a relevant decision problem. This is often a matter of qualitative judgement, influenced by product and production system structure, operational constraints, company-specific practices and tradition, but it strongly affects the performances of the assembly system. In fact, while the basic trade-off is labor cost vs space occupation and WIP holding cost, even additional factors, such as degree of quality control and assembly support, flow control and visibility issues, ergonomics, material security, obsolescence, compatibility with large product variety and frequent mix variations, ease of implementation etc., may favor one policy respect another in a specific manufacturing context. Nevertheless, Hua and Johnson (2010) note that literature on feeding policy selection is confusing, with research showing contrasting results in similar manufacturing environments. Therefore, many industries are uncertain about where and when each type of system should be used, and may switch several times from kitting to continuous supply without being sure which is best for their environment. Criteria to choose between alternative parts feeding methods have been developed in the literature, but existing methods are not exhaustive or are difficult to apply on the shop floor, being often based on mathematical optimization approaches. Bozer and McGinnis (1992) develop a kitting vs LS descriptive model. Faccio (2014) compares kitting and JIT solutions, even considering hybrid policies, while Sali et al. (2015) compare kitting, LS and sequencing solutions. Battini et al. (2009) compare trolley to work station, pallet to work station and kit to assembly line approaches. Caputo and Pelagagge (2011) suggested an ABC class-based approach to develop hybrid feeding policies including Kitting, JIT and LS. Linear programming has been used by Caputo et al. (2015c) to assign a different feeding policy (i.e. kitting, LS or JIT) to each single item in order to minimize total delivery cost, and by Limere et al. (2012) to choose between Kitting and LS. Overall, a systematic approach to the selection of material supply systems based on detailed cost models, including all policy options, and simple enough to be applied in the shop floor is not yet available.

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In order to provide a more practical solution to this problem in this paper the effect that relevant and measurable parts features (i.e. unit volume, weight, and cost) have on parts feeding cost is explored by developing suitable economic models. This allows to identify cost breakeven points, based on basic parts attributes, in order to map areas where each feeding policy is more convenient respect other options. As a result, the choice of feeding policy can be made quickly on a part by part basis only resorting to an inspection of the relevant parts features, without utilizing complex global optimization procedures. The paper is structured as follows. At first economic models are developed for the three considered policies to estimate the feeding cost of each part type based on its relevant attributes. Then a parametric analysis is carried out by varying the value of each part attribute in order to determine cost breakeven points between the alternative policies, if any. Effects of changing container size is also examined and a sample mapping of the multiple dimensions decision space is provided to assess each policy convenience areas for direct selection of the feeding policy. Results discussion conclude the paper.

2. COST MODELING OF PARTS FEEDING POLICIES

In this paper we assume that a single model assembly line has to be fed with parts in order to obtain a predefined constant daily production volume D (units/day). The time horizon for cost estimation is one day. We compute the overall cost of supplying a part type to a generic workstation utilizing that part, located at a given distance from the warehouse. In case of kitting kits are delivered from the kitting area located at the warehouse I/O station to the first station of the line, then they travel along the line together with the product being assembled (traveling kit). In JIT policy material is resupplied with a lead time LT in separate containers dedicated to each component type. The required number of containers, thus depends on the daily consumption of parts and the replenishment LT. In line stocking each station holds separate containers (usually one) for each distinct component it uses, periodically resupplied at time intervals which depend from the adopted containers capacity and parts consumption rate. Constant-speed vehicles or walking operators are used to transport kits and components containers. However, different kind of vehicles, and containers sizes, can be used for different feeding policies. Empty containers are returned back to the central warehouse for replenishment. Cost items included in the model are personnel cost (this includes operators to fraction bulk cartons and pick components in the warehouse, to deliver materials to the workstations, as well as workforce engaged in kits preparation and picking time at the line), investment cost (containers, storage racks and transport vehicles), WIP holding cost (proportional to the average level of inventory at the stations), and space occupation cost which is proportional to the floor space occupied by accumulated stock at the workstations and specific floor space cost.

We define C^M_p the equivalent workforce cost (€/day), C^E_p the equivalent investment cost (€/day), C^{WIP}_p the work in process holding cost (€/day), C^S_p the space occupation cost (€/day) incurred when policy *p* is selected to deliver the component, being *p* = [1, 2, 3] the policy identifier. Namely p = 1 in a kitting policy, in a LS policy p = 2, and in a JIT policy p = 3.

2.1 Computation of workforce cost

2.1.1 Kitting policy

In a kitting policy the equivalent number of kit containers required to hold a parts per unit end item is

$$n_{cont\,kit} = \max\left(\frac{v\,n}{V_C};\frac{p\,n}{p_{\max}}\right) \tag{1}$$

which depends on containers volume (V_C) or their allowed weight (p_{max}) as well as the unit weight (p), the volume (v) and the consumption of parts (n) per unit end item of the considered part type. The total equivalent number of containers (used once a day) required to manage the part for the daily production is $n_{cont\,kit}$ D. Workers are required to pick components at their storage locations in the warehouse to feed the kitting area, to place individual parts into kit containers, and to move containers to the start of the line. The average time to reach the part storage location and return to the kitting area is ($t_{r/s}$). When the storage location is reached the operator can pick a quantity of parts enough to complete Q separate kits (with Q integer and ≥1) or retrieve Q different part types that are stored in nearby locations in order to avoid multiple trips. Average time required to pick and kit one unit of a part type is t_{pick} and includes counting/weighting of parts to ensure that the right number is included in the kit; preparation of components before insertion in the kit (i.e cutting to measure, package removal, cleaning and quality control); kit preparation (insertion of parts in the right sequence and in the proper housing slot, including correct positioning control). The equivalent number of daily moves for the part type (from the warehouse to the line with full containers and from the line to the warehouse with empty containers) is $2\ n_{cont\,kit}\ D/\omega$. , being ω the number of container simultaneously transported by the material handling vehicle ($\omega = V_L/V_C$ where V_L is the loading volume of the vehicle and V_C the container volume). We assume that each trip involves k operators and that the one-way trip time is L/V_V, estimated on the basis of plant layout (L is the distance between kitting area and the line first workstation) and material handling vehicle average velocity (V_V). The time required to pick components at the workstation by line operators, (n D) 2 L_{WSK}/V_O, is also included as it may change according to the material handling policy. In this case V_O is the operator walking velocity who needs to travel 2 times the trip L_{WSK} from the assembly position to the kit storage point at the workstation. Time to search for the right part is neglected as parts are already ordered and properly presented to the picker. From the above assumptions the equivalent number of daily workers required to prepare and move the equivalent number of kits required by the considered part can be computed assuming that each operator works a daily shift of h hours and has an efficiency η_{op}. Then the number of workers times their wage rate C_{op} (€/day), allows to compute the overall personnel cost.

$$C_1^M = C_{op}\left\{\frac{\left[\frac{t_{r/s}}{Q}+\left(t_{pick}+\frac{2L_{WSK}}{V_O}\right)n\right]D+\left[\left(\frac{2\,L\,k}{V_V}\right)\frac{D\ n_{cont\,kit}}{\omega}\right]}{\eta_{op}\ h}\right\} \tag{2}$$