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Impact of unit load size on in-plant materials supply efficiency

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ABSTRACT

The unit loads, e.g., plastic containers or EUR-pallets, used in an assembly plant can have a significant impact on time efficiency, and hence cost, of both the materials supply and the receiving assembly stations. Smaller unit loads can reduce the time the assemblers spend fetching parts. However, larger unit loads result in fewer moves for a given volume of materials, which implies efficient in-plant materials supply. The current paper explores how the time efficiency of in-plant materials supply is affected by the size of unit loads. Based on the case study, it is clear that the efficiency of the in-plant materials supply is not proportional to the size of the unit loads. There are fundamental differences between how large pallets, compared to smaller unit loads, are delivered, meaning that the increased delivery frequency required for smaller unit loads does not necessarily result in an increased man-hour consumption.

1. Introduction

The configuration of a materials supply system within an assembly plant can have a significant impact on the performance of both the materials supply and the receiving assembly stations. Several authors have stressed that within a materials flow, processes should not be designed in isolation, but rather, the overall performance of the materials flow should be in focus, so that sub-optimisation is avoided (e.g., Kulwiec, 1985; Wu, 1994; Jones et al., 1997; Cochran et al., 2001; Johansson, 2007). Accordingly, because of the impact that the in-plant materials supply can have on assembly performance, the assembly operations should be considered when the in-plant materials supply system is designed (Finnsgård et al., 2011). However, there is a lack of knowledge regarding how in-plant materials supply should be configured to support efficiency in both assembly and in-plant materials supply.

The interface between assembly and in-plant materials supply is to a large extent constituted by the unit loads used, e.g., containers or pallets. The unit loads can affect both the configuration (e.g., in terms of materials handling equipment and delivery routing) and the efficiency (in terms of resource consumption) of an in-plant materials supply system (Noble et al., 1998; Castillo and Peters, 2002). Furthermore, the unit loads constitute an important part of the parts presentation at the assembly stations, thereby affecting assembly performance. Previous research has shown that smaller unit loads, used for presenting parts at the assembly stations, can improve flexibility (Wänström and Medbo, 2009) and ergonomics (Neumann and Medbo, 2010; Finnsgård et al., 2011) at the assembly stations, as well as increasing efficiency of the assembly by reducing the time the assemblers spend fetching parts (Wänström and Medbo, 2009; Neumann and Medbo, 2010; Finnsgård et al., 2011; Hanson, 2011). However, no research reports can be found focusing on the impact that the use of small unit loads has on the performance of the in-plant materials supply system.

Using larger unit loads, e.g., EUR-pallets, can result in efficient in-plant materials supply, since the large unit loads imply that fewer moves are required for a given volume of materials (Hales and Andersen, 2001; Neumann and Medbo, 2010). Hence, it seems there is a potential conflict between assembly efficiency and in-plant materials supply efficiency, as small unit loads can support assembly efficiency and large unit loads can support in-plant materials supply efficiency. Without an understanding of this conflict, there is a risk that in-plant materials supply systems will be designed based on the wrong objectives, without considering the efficiency of both in-plant materials supply and assembly, and that poor overall performance will result due to sub-optimisations. Accordingly, there is a need for studies comparing the use of small unit loads to the use of large unit loads in the context of in-plant materials supply. Complementing the previous studies that have shown that small unit loads can improve efficiency at the assembly stations, the current paper has the purpose of exploring how the efficiency of the in-plant materials supply is affected by the size of unit loads.

The paper is based on an in-depth case study in a Swedish assembly plant in the automotive industry. In the studied plant, a

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transition to smaller unit loads has been made, greatly affecting the configuration of both assembly and in-plant materials supply. The main aim of the transition was to achieve compact assembly stations with parts presentation that supports efficient assembly. To support this, however, the in-plant materials supply too has had to undergo considerable changes. A previous study has been performed within the same assembly plant, analysing the impact that the change in parts presentation at three assembly stations had on assembly performance and on the conditions at the assembly station (see Finnsgård et al., 2011). The current paper extends this study by focusing on the in-plant materials supply, rather than the assembly. Specifically, the paper focuses on the materials supply from in-plant storage to the assembly stations. The paper describes how this materials supply was reorganised to provide better support to the assembly and analyses how this, in turn, affected the efficiency of the in-plant materials supply.

2. Frame of reference

Tompkins et al. (2010) discuss a definition according to which a unit load is "a single item, a number of items or bulk material which is arranged and restrained so that the load can be stored, and picked up and moved between two locations as a single mass". This definition thus includes different types of containers as well as singular units without containers. Egbelu (1993) defines the unit load as a container, box, bin or pallet with its part contents, assumed to be homogenous, and the number of given parts in the unit load is given for each part. Hanson (2011) studies the concept of minomi, which is a unit load where no container is used, meaning that very space-efficient parts presentation can be achieved. In this paper, the definition by Egbelu (1993) is used, with the addition of the minomi concept, or singular units without containers as described by Hanson (2011) and Tompkins et al. (2010).

As stated in the introduction section, the use of a larger unit load is often stated to reduce the frequency of moves and, thereby, the total move distance and the handling cost (Tompkins et al., 2010). For example, Hales and Andersen (2001) discuss the size of packaging and point out that a large packaging holding a large number of parts will reduce the number of transports necessary, but they also recognise that there are drawbacks associated with the use of large packaging. The levels of work-in-process are likely to increase with large packaging and the space requirements are larger at the points of loading and use.

Egbelu (1994) states that the characteristics and size of a unit load are tightly integrated with the other aspects of the materials handling system, such as facilities layout, manpower requirements and handling equipment. For a description of the supermarket concept, refer to Battini et al. (2010) and for literature on the location of supermarkets, refer to Emde and Boysen (2012a, 2012b). The characteristics of the unit loads, e.g., in terms of dimensions and weight, constitute restrictions for which handling equipment can be used (Bozer, 2001). Furthermore, depending on the size of the unit loads, different approaches for in-plant materials supply are needed in order for efficiency to be achieved (Battini et al., 2009). For example, when large unit loads are used, a forklift can deliver a large number of parts from one point to another (Baudin, 2004). When smaller unit loads are used, a tugger train can instead be used for delivering a large number of unit loads to different locations on the same delivery round, according to a so-called milk-run approach (Baudin, 2004). Related to this, Hales and Andersen (2001) distinguish between direct and indirect systems for moving materials, where in direct systems, different materials move separately and directly from origin to destination, and in indirect systems, different materials are moved together on the same equipment, with several potential stops on each round. As discussed by Baudin (2004), an in-plant materials supply system based on forklifts is likely to have a relatively low level of utilisation of the forklifts, as redundancy is needed to ensure that a forklift is available when needed. The predictability of a milk-run system may be used to achieve a higher level of utilisation of the delivery equipment and of the delivery operators.

Tightly related to how parts are delivered within an assembly plant are the principles for initiating replenishment (Lage Junior and Godinho Filho, 2010). In this respect, a distinction is often made between whether materials are replenished by means of "push" or "pull" principles, where "push" principles are based on replenishing in anticipation of a need, whereas "pull" principles are based on replenishing on request (De Toni et al., 1988; Bonney et al., 1999). If parts are to be "pulled" from the receiving operations, the replenishment signals should not be based on anyone's subjective assessment, but they should be based on actual consumption (Baudin, 2004). Otherwise, replenishment may not be performed in accordance with consumption and the materials flows may therefore not show the same level of smoothness, as they ideally should. A smooth demand for materials results in an even level of workload and, hence, in an even capacity utilisation (Boysen et al., 2009).

The analysis of the case study presented in the paper is based on the literature referred to above. Hence, in the analysis, the paper links the changes in efficiency to the changes that were made to the configuration of the in-plant materials supply. The paper considers not only the size of the unit loads, but also the types of unit loads used, the types of handling equipment, the principal configuration of the material flows and the principles for initiating replenishment, as all of these aspects are relevant in relation to the efficiency of the in-plant materials supply system. Fig. 1 presents the analysis model used in the paper, illustrating that the unit load size can have both a direct effect on the in-plant materials supply efficiency, and an indirect effect, by influencing the in-plant materials supply configuration. In studying in-plant materials supply efficiency, the paper focuses on the man-hour consumption in the in-plant materials supply, as this is closely related to operational cost and can be affected by the size of the unit loads used.

3. Method

As stated in the introduction chapter, the paper is based on a case study from a company within the automotive industry. The case was selected due to the case company's planned transition from an in-plant materials supply system based on large unit loads to a redesigned system with smaller unit loads. This provided an opportunity to perform a detailed study of the same basic system, utilising two different sets of unit loads.

The case includes three assembly lines and the in-plant materials supply supporting them. In the case company, a comprehensive redesign was made of the in-plant materials supply and parts presentation. A main aim of the redesign was

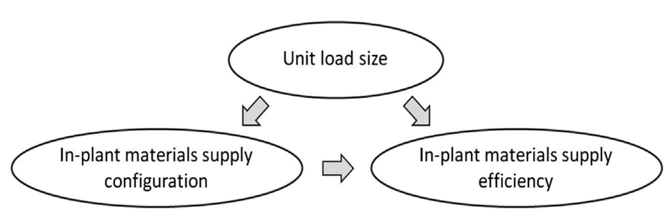

Fig. 1. The analysis model used in the paper.