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A planning approach for the implementation of Lean in-house transport systems in brownfield plants

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Abstract. In order to meet requirements of a high-frequency supply with small batch sizes, milkrun systems and pull-control are the key concepts for Lean in-house transport. In brownfield plants narrow layouts, transportation between several buildings, large carrier units and multi-storey production sites limit the use of milkrun systems. Existing planning procedures mainly address structure and layout planning and the design of transport technology. Thus, the focus is on the selection of a wide range of manual, mechanical or automatic techniques and not on the definition of Lean processes for in-house transport. This paper addresses interdependencies, boundary conditions and restrictions within the design of in-house transport in brownfield environments. A first classification and dimensioning of transport forms is applied in a case study. Therefore, initial steps towards a structured planning method for Lean in-house logistics are given.

1 Introduction

With regard to Lean production, lead times in logistics are a key success factor for competitive production sites. The scope of this paper are internal logistics processes of a production site that are analysed for the design of Lean in-house transport. Conventional static planning approaches are not sufficient for determining the influencing factors and dynamic interactions in practical applications [1]. Therefore, the focus has to be set on planning steps for defining lean material flows for in-house transport with a structured, heuristic limitation of choices. The offered decision making hierarchy is supposed to simplify the often iterative and overlapping planning process.

2 In-house transport systems

2.1 Classification and definition

Different systematizations exist for structuring of logistical systems and resulting classifications of in-house transport differ [2-4]. From institutional perspective, in-house transport is an operational function of internal logistics [3, 5].
Transport systems consist of transport connections and transport nodes for incoming and outgoing material flow [6]. In addition to pure location changes, logistical functions such as stacking, turning over, picking or releasing occur before and after an interruption during the actual transport process [5]. In this paper, this broadened definition for internal transports is used. Therefore, transportation and logistical functions being directly connected with a transport process within the

company's boundaries are summarized as in-house transport system.

2.2 Holistic decision making in planning

2.2.1 Design elements of in-house transport systems

Transport unit, **technical design** and **transport organisation** are the three major design fields of in-house logistic systems [5].
Transportability of material and goods can be achieved by the use of carrier units. The combination of both forms the **standardised transport unit**. The Lean objective is to use consistent transport units as the most standardised link between the stages of a value stream in order to be able to build efficient transport chains [3-5]. Therefore, unified forms and dimensions allow the combination of transport goods to larger units and enable minimized disruption in transport chains [3].
Considering existing guidelines, the **technical design** of in-house transport can be done according to numerous criteria such as degree of automatization, mobility, direction of transport and transport sector [5]. Two basic types of transport equipment with a vast number of variations can be found: Continuous conveyors and discontinuous conveyors [4, 6]. In practical application, planners repeatedly resort to the same solutions which have already proven to be successful [7]. Planning the **transport organisation** is subject to a high combination complexity and subsequent decisions. A hierarchy system for planning **transport form**, **supply-delivery-systems** and **transport control** is still lacking in literature.
In order to meet requirements of a high-frequency **transport form** with small batch sizes, milkrun systems are a key concept for Lean in-house transport [7-10]. Other basic forms such as direct transport, worker self-supply and rigid conveyor technology can also be taken into account [9, 11, 12].
In-house material flow requires changing quantities and compositions of the transported goods [13]. For the realization of the entire process chain, the existence of a **supply system** at the transport source and a **delivery system** at the transport sink is necessary. Warehouses, supermarkets, FIFO-lanes and buffer areas function as material source and/or sink [14]. In addition, direct delivery without any form of buffering is possible [11].
Within the scope of production planning, demand-driven (Push) and consumption-driven (Pull) **control concepts** for transport are fundamentally differentiated [5, 13, 15]. Additionally, a lot-size of one can be processed or transported on the basis of a "one-piece-flow" between two synchronized processes with the same takt [16]. As a further alternative, transport-in-takt operating according to a timetable independently of upstream or downstream processes, is used. Depending on whether the upstream or downstream process is controlled, the clocked route can support push or pull [14]. Frequently, transport processes are also triggered by individual orders.

2.2.2 Interactions and interdependencies

A network of interdependencies occurs in decision making. Certain carrier units are only suitable for transport of certain loading units and the right use of transport equipment. In addition, interactions between components within the transport organisation are recognisable. The characteristics of different supply and delivery systems as well as the control logic show that their selection depends on the chosen transport form. For example, the milkrun systems in automotive industry are frequently linked to supermarkets as delivery systems. These are often supplied with material by a fixed clocking as control logic [13] or by a kanban system [11]. In addition to the dependency on the transport form, there are direct interactions between supply and delivery systems and transport control. For example, a pull-control is necessarily realized when a subsequent material demand is triggered by a free space on a FIFO-Lane [9, 13]. Mutual interdependencies in the selection of transport organisation, technology and units are identified, as shown in figure 1.

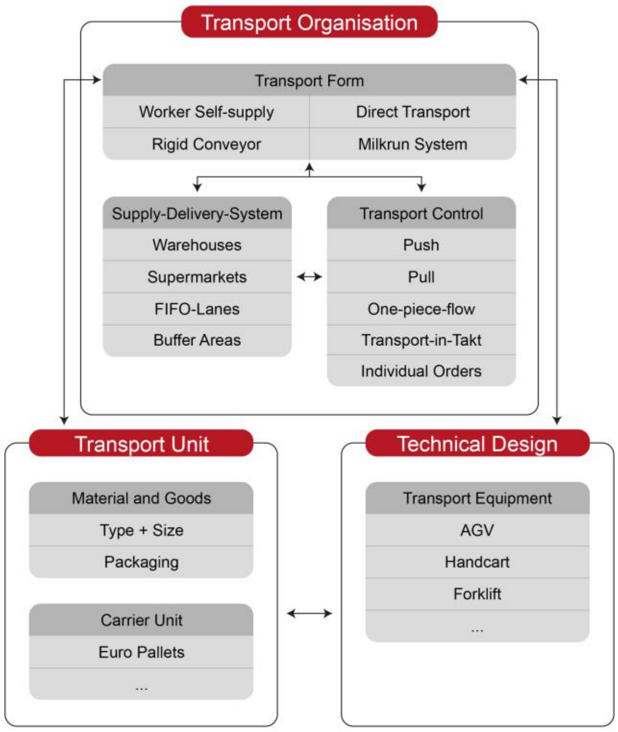

Figure 1: Interdependencies in planning in-house logistic systems.

As depicted, the decision on **transport form** is identified as central within the dependency relationships. It is also conspicuous that no direct cause-and-effect relationships but bilateral interactions occur. The direction of impacts depends on the hierarchy in decision making.

3 Existing methods for logistics and material flow planning

In literature, the process of logistics planning is subdivided into successive steps. In spite of partly different definitions, a typical sequence can be identified [5, 6, 11, 17, 18]. Nevertheless, iterative cycles are necessary [1, 6, 21].

3.1. Lean logistics and material flow planning

Material flow planning is part of medium-term logistics planning [1]. Starting points are new structural measures or efforts to improve material flow on the basis of detailed existing guidelines [19-22]. The flow of materials from procurement warehouse, through production processes and intermediate storage to sales store is planned subsequently. If *Lean logistics* is chosen as main principle for the methodical support, the "**Line-back-planning**" is the main approach [12]. The line-back planning principle considers the entire logistic chain reversely, starting from value-adding processes seen as customers [13, 23]. However, decisions for selecting the subcomponents for each source/sink seen as a customer quickly reaches a comparatively high complexity and even conflicting objectives. Neither a planning in direction of material flow nor the "line-back"-principle can be fully adhered to in practical implementation [1, 6].

3.2 Conclusion for planning Lean in-house transport systems in brownfield plants.

In view of the complex interrelationships which are to be planned and implemented, a shift from mechanistic to heuristic design is necessary to limit the amount of possible solutions [24]. In brownfield plants narrow layouts, transportation between several buildings, large containers and multi-storey production sites complicate and limit the use of milkrun systems. Therefore, fixed boundary conditions have to be taken into account at an early planning stage. A contemporaneous analysis of all sources/sinks offers new possibilities for route developments within milkrun systems. As stated in figure 1, the transport form is the central variable for in-house transport systems. More focus has to be placed on checking the compatibility of the subcomponents and adhering to the given constraints to achieve optimal practical implementations.

4 Planning Lean in-house transport systems

A structured identification of fixed and soft boundaries is necessary for the transition from ideal planning phase to real planning phase. The aim is to limit selection options regarding organization, transport unit and technical design for transport processes. Based on literature research, a general requirement catalogue and an associated requirement list are created [25]. The requirements, which act as boundary conditions, are divided into nine internal and three external categories as shown in figure 2. For an evaluation of consequences of boundary conditions, they are divided into hard and soft boundary conditions at an early stage [4-6, 8, 11, 20, 22].

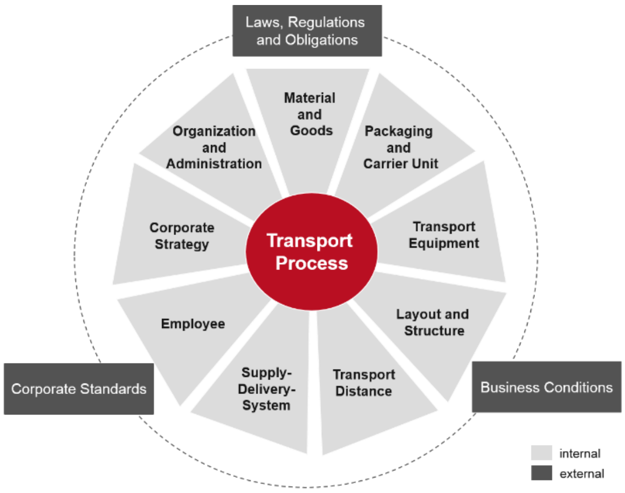

Figure 2: Categories of boundary conditions.

A selection matrix helps to make dependent decisions in choosing suitable transport processes for Lean milkrun systems, taking into account the boundary conditions. The central position of the transport form is taken as basis for the development of a matrix [14, 22]. Following the line-back principle, **transport processes** are classified and applied as shown in figure 3.

		Milkrun System	Direct Transport	Rigid Conveyor	Worker Selfsupply
Material and Goods	Demand per Time	medium-low	high-low	high	high
	Stability of Demand	steady	unsteady	steady	steady-unsteady
	Dimensions	small (big)	big-bulky	big-bulky	small
	Weight	low	heavy	heavy	low
	Handiness	manually	not manually, possible additional handling	not manually, technical aid necessary	manually
Carrier Unit	Type + Size	small (mobile large load carrier)	large load carrier	small-large load carrier	small (mobile large load carrier)
Transport Distance	Source-sink Distance	high-medium	short, low availability of the sink	medium-short	high availability of the sink
Transport Connection	Bundling	necessary	not necessary	not necessary	not necessary

Figure 3: Selection matrix

The selection of the transport form is made primarily on qualitative statements on characteristics of transported material within the processes. In addition, existing transport equipment as well as information on the length of transport from source-to-sink and the necessity of bundling goods form the framework conditions of decision making. Organizational and technical follow-up decisions are made. Based on segmentation via classes of goods, buildings, floors and frequency, the implementation of new milkrun routes can be done.

5 Implementation and next steps

200 transportation processes within one production site of a producing company were observed and structured in a case study [19-20]. A division in 8 different classes of transport processes according to different **transport units** (see figure 1) is conducted. Based on the presented method, the preselection of six classes for new milkrun stations is done. Additionally, two classes of goods are chosen for direct transport. The requirements catalogue, the requirements list and the selection matrix are integrated as a tool from design phase to executional planning. Both tools are a basis for the further development of a holistic system planning of Lean in-house transport in brownfield plants with the following principles:

- Focus on Point of Demand
- Process Stability
- Synchronised Pull, Flow and Takt
- Improvement Philosophy

The presented tools revealed new combination possibilities for routing and scheduling of Lean transport. In the next step, the **voice of the customers** (sinks of material and goods) is added. In addition, interfaces to adjacent planning areas, for example on the supply and delivery systems, are to be defined in order to enable synchronized processes.

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