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Synchronized production and logistics via ubiquitous computing technology

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ABSTRACT

The integration of manufacturing and logistics has drawn widespread research attentions in recent years. This paper focuses on the Synchronized Production and Logistics (SPL), which is operational level integration. SPL is defined as synchronizing the processing, moving and storing of raw material, WIP and finished product within one manufacturing unit by high level information sharing and joint scheduling to achieve synergic decision, execution and overall performance improvement. Through analysing the requirements and challenges in real life industry, the ubiquitous computing is adopted as an enabling technology and an Ubi-SPL (Synchronized Production and Logistics via Ubiquitous Technology) framework is proposed. This framework is consists of four layers, which creates a close decision-execution loop by linking the frontline real time data, user feedback and optimized decision together. A real life case study of applying Ubi-SPL solution in a chemical industry has been conducted. The implementation results show that the proposed Ubi-SPL solution can significantly improve the overall performance in both production and logistics service.

1. Introduction

Managing manufacturing operations poses significant challenges in today's fierce competition environment. The firms no longer content the traditional thinking that only achieve excellence in one dimension with major priority and sacrifice other aspects. The dimensions of production cost, inventory cost, as well as transportation cost are not to be traded-off against one another but need to be simultaneously prioritized.

To meet these challenges, all manufacturing segments should work closely with each other and conduct the integrated approach, in which various decisions (e.g. supply process, distribution, inventory management, production planning, facilities location, etc.) are wrapped into a single model and requirements of all units are simultaneously considered to perform an overall optimization. In particular, the production and logistics are transforming from the separate and independent activities into the coordinated and synchronized manner [1].

The integration of manufacturing and logistics has drawn widespread research attentions in recent years. It is well recognized that there is a greater opportunity for cost saving by considering the supply, production, warehouse, and distribution in a cooperated manner. As shown in Fig. 1, the integration involving production and logistics can be conducted in strategical level, tactical level and operational level.

In the strategic level, research efforts focus on the integrate design and decision about location, plant capacity, and transportation channels ([2–4]). Normally the integration in this level refers to long term decision (several years). The typical research problems in this level include where to build the plant and distribution center, what the capacity of the plant and distribution center should be. See [5] and [6] for reviews.

In the tactical level, problems about integrated inventory replenishment decisions with multi-stage supply chain are discussed ([7–9]). The typical research problems in this level include how much to produce and how much to ship in a time period, how long the production cycle/distribution cycle should be, how much inventory to keep, etc. The typical decision period is several months.

This paper focuses on the operational level integration. The production–logistics integration in this level have following features:

1. *Scope of Integration*: production and logistics within one manufacturing unit (one factory with several plants and a warehouse).

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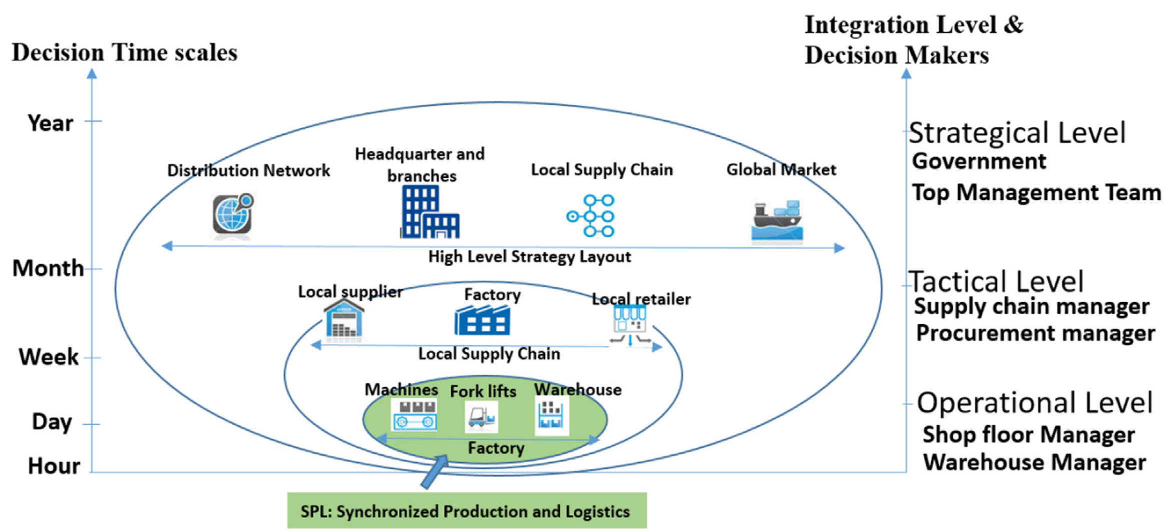

Fig. 1. Positioning of SPL in Production–Logistics integration.

2. *Time scale of Integration*: short term decision from hours to days.
3. *Typical activities*: (1) Processing: production activities on machines in each plant (2) Moving: internal transportation of raw materials, WIP (work in progress) and finished product between warehouse and plants. (3) Storing: short term inventory of raw materials/finished product in warehouse and temporary WIP buffering in plants.
4. *Typical objects:* individual operators, jobs, machines, internal transpiration equipment (forklift, trolley and pallet jack), storage space (shelfs in warehouses and buffers in plants)
5. *Typical decisions*: when and on which machine to process a job, when and by which vehicle to transport materials and finished products, which route for vehicle traveling, where and when to pick up/ put away products and materials, etc.

In previous articles, the integrated production and distribution operations has been investigated. Chen [1] has defined the tactical and operational level integration as "explicit production distribution" (EPD) model. In the EPD model, the warehouse and storage operation are not included. To our knowledge, there is no suitable term to describe the operational level integration of production and logistics (including storage and transportation) in the literature. Here we use the term Synchronized Production and Logistics (SPL) to represent this special integration case. SPL is defined as synchronizing the processing, moving and storing of raw material, WIP and finished product within one manufacturing unit by high level information sharing and joint scheduling to achieve synergic decision, execution and overall performance improvement.

Through an extensive investigation in industrial companies, it can be found that majority of contemporary manufacturing enterprises face following fundamental problems in production and logistics synchronization.

(1) Although most manufacturing companies have ERP system, the poor paper based data acquisition method in shop floor leads to complicated computer input work. The records in ERP system are always delayed. The transparent monitor and control is hard to achieve.
(2) Manufacturing companies have certain methodologies on production scheduling, but the decision-making support system in internal transportation and warehouse operation are highly ignored. The shop floor manager, internal vehicle derivers and warehouse manager have their own objective functions, which often conflict with each other.
(3) Uncoordinated production and warehouse operation are very common. Products in one customer order cannot be finished at the same time because each plant do not have synchronized scheduling. Materials and WIP are waiting for a long time in temporary buffer because material handling staff cannot efficiently move them to the next stage. Warehouse is always crowded because of the poor synchronization of production and internal transportation.

In order to deal with above challenges in SPL, it is necessary to development a total solution with interdisciplinarity approach, which involves software engaging, network technology, operational research and industrial engineering. Based on previous research, Ubiquitous Computing should be a suitable enabling technology to construction such total solution. Ubiquitous computing is a concept in software engineering and computer science where computing is made to appear everywhere and anywhere [10]. As an application of ubiquitous computing in the manufacturing sector, ubiquitous manufacturing provides an environment in which manufacturing is done everywhere and anywhere. Ubiquitous manufacturing enables ubiquitous, convenient, on-demand network access to a shared pool of configurable manufacturing resources (e.g., software tools, equipment, and manufacturing capabilities) [11].

The Aim of this paper is to build up an easy-to-deploy and simple-to-use Ubi-SPL solution (Synchronized Production and Logistics via Ubiquitous Technology), which can achieve: (1) Real time and convenient data capture from shop floor and warehouse, (2) Seamless information sharing among production department and logistics department, (3) Joint decision and simultaneous optimization of production scheduling, internal transportation scheduling, and storage space planning, (4) Cooperative executions of product processing, moving and storing and (5) Rapid and systematic response mechanism for local and outside disturbances.

The rest of the paper article is organized as follows. Section 2 reviews the current development of SPL and the application of ubiquitous technology in manufacturing. Section 3 analyses the current problems of SPL faced by real life industry and summarizes the design consideration of the Ubi-SPL solution. Section 4 develops the framework of Ubi-SPL and the key function modules in the framework are described. In Section 5, a real life case of applying Ubi-SPL solution in a chemical company has been studied.

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