Mobile Factory Network (MFN) – Network of Flexible and Agile Manufacturing Systems in the Construction Industry

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Abstract. The concept of the "On-site Factory" consists in the temporary use of fully functioning mobile mini-factories or production cells at the site of consumption. Mobile Factories are well suitable for situations in the construction industry with long distances and therefore high logistics costs. The advantage of this concept is its economic efficiency combined with a maximum of flexibility and a Just-in-Time (JIT) supply. By a high degree of reconfigurability and scalability of the On-site Factory, it can be adapted to its individual mission and the quantity demand at the construction site. This research discusses the need for new and innovative JIT solutions for the construction industry and addresses the specific case of networks of mobile on-site factories. The creation of a Mobile Factory Network (MFN) shows an interesting new and innovative business model for decentralized manufacturing on-site. The research shows a possible form of network structure and organization as well as its advantages and potential for the construction sector.

Introduction

Manufacturing networks allow multiple partners to bundle their forces through a synergistic combination of their own core competencies and resources and thus to be more competitive on the market. Particularly in the construction industry, such networks and network partners are becoming increasingly important to handle projects efficiently. The goal in the construction industry is to provide better cost efficiency and shorter construction times, while enhancing the construction quality. Consequently, organizational structures, processes, and technologies to carry out the construction of buildings in an efficient and economical way must also be developed [1].

Today many Construction and industrial Engineer-to-Order (ETO) companies are under pressure to reduce their costs while minimizing the completion time on site. Companies have worked in recent years to industrialize their manufacturing processes, to introduce prefabrication by standardization of their products and to work in collaborative networks. In construction supply chains the installation on-site stands for the consuming process (customer). Finished parts should be delivered to the construction site JIT with short lead times and low stocks. This requires a synchronous production for both, the construction site and the supplier fabrication shop. Supplier lead times are very often longer than the possible accurate foresight regarding on-site installation. Thus, JIT deliveries of components are usually only possible through high buffer stocks within the supplier fabrication shop or the construction site [2].

Prefabrication should be “pulled” according to the construction progress. In usual construction supply chains, manufacturing and prefabrication processes are disconnected from the installation on-site and scale effects of large batch production and economics of transportation charges determine the assembly sequence on site. [3].

The JIT ideal is elimination of buffers (materials or time) and the achievement of one piece flow [4]. Increasing market dynamics require manufacturing systems to become even more flexible [5]. In

the future, long-established paradigms of production will continue to change in order to meet the demand for even more individuality, customer-specific product variants and shortest delivery times within the meaning of the term "production on demand" [6]. Particularly due to the increasingly loud request for JIT deliveries as well as sustainable and ecologically delivery processes, the concept of decentralized and mobile manufacturing systems shows a potential approach, because the production takes place at the point of consumption. It needs modern organizational models for the coordination and management of small, flexible and mobile production units in manufacturing networks, which produce locally in mini and micro production systems. The main advantages of such decentralized production structures is a higher flexibility to react to individual requirements as well as lower logistics costs and shorter delivery times due to their proximity to the customer.

Manufacturing Networks

Nowadays, collaboration networks are very important for any organization to share information, resources and responsibilities to achieve a common goal. Thus, enterprises are collaborating with other enterprises in complex value chains to eliminate waste and reduce costs [7]. In the last years the concept of collaboration in collaborative networks has become an important topic in science and practice. Their does not exist one universal model for network collaboration in manufacturing, but a large variety of different forms. In the classical supply chain view we can find relatively stable networks with well-defined roles that require only minimal coordination and information exchange, while more dynamic structures are emerging in industry [8]. Virtual manufacturing networks are goal-oriented focusing on single projects or business opportunities [9, 10] and characterized as a temporary network of enterprises that join skills and resources to respond to business opportunities. This requires a high agility, flexibility and dynamism for these organizations [11]. Important criteria for network are typically: punctuality, partnership synergy, reliability, cost, economic situation, trust, quality, etc. [12]. Networks help to improve cooperation by communicating targets and empowering decision maker’s in decentralized systems [13].

In this work, collaborative networking in the construction industry is taken up as well. This research shows a concept of Mobile Factory Networks (MFN) where contractors have the opportunity to obtain mobile production units using them temporarily on the site and returning them at the end to an external, specialized network partner. Before discussing this form of Mobile Factory Network, the concept of mobile factories will be briefly described.

Concept of Mobile On-Site Factories

Construction is originally an on-site production: Construction corresponds to site position manufacturing and assembly as opposed to factory position manufacturing in which the product has to be moved to the construction site [14, 15]. The incorporation of off-site manufacturing in the construction process consists usually in a pre-assembly or prefabrication of components installed at the construction site. In recent years, especially the principles of industrialization in construction through prefabrication of factory-finished elements have gained more and more acceptance in the construction sector [16]. Prefabrication of modular elements increased and led to a higher impact of work in the manufacturing hall of Engineer-to-Order companies [17]. However, there are some limitations and disadvantages of an off-site prefabrication [18, 19, 20]:

- Prefabricated items will have a defined lead time and this has to be considered from the beginning
- Thought must also be given to the arrival of the pre-assembled items on-site
- Parts may need to be adjusted on site (for complex parts and uncertain tolerances on-site)
- Breaks in the supply chain through the transport from fabrication shop to the installation site
- Thereby increasing organizational and planning effort for material logistics
- JIT delivery could not always be guaranteed or only through buffer stocks at the fabrication shop or on-site.

At the construction site JIT for supplier deliveries is not always easy [2]. Large schedule buffers between suppliers and construction may shield the contractor from the impact of late deliveries, but shielding is expensive [21]. The realization of JIT in construction through an improvement of the synchronization between off-site manufacturing and on-site installation is actually highly discussed in research [2, 3, 18, 22, 23]. Nevertheless, it is also important to extend research activities for other innovative solutions where the benefits of off-site fabrication can be combined with those of on-site fabrication. Mobile and scalable mini-factories play a major role to reach this goal. Through this type of "mobile On-site Factories" components can be produced JIT in an industrial environment and process at the point of consumption. Several authors [6, 24, 25, 26, 27] recommend On-site Factories, as combination of advanced manufacturing in micro-factories and industrial construction on-site. The "factory on-site" consists in the temporary use of fully functioning mobile mini-factories or mobile production cells at the site of need or consumption (see Fig. 1). Through a highly flexible as well as scalable design they can be very well suitable for different temporary manufacturing requirements, reducing transport costs and delivery times. Particularly, this concept of a mobile factory is well suitable for situations with long distances and therefore high logistics costs like fabrication of components on the construction site. The application of On-site Factories is particularly useful in the following cases and can be resolved by the use of standard ISO containers [27]:

- Long distances between construction site and off-site manufacturing
- Logistically rational shortening of the supply chain (in case of distant suppliers)
- High uncertainty in material and component deliveries
- Difficult or impossible transport of large or heavy components or building modules
- Complexity of parts due to the need to adapt them on-site
- No space for material inventory on the construction site and therefore "production on demand"
- High necessity of punctual JIT delivery of parts to avoid delays in the construction process
- Unpredictable building progress (caused by changing weather conditions and so on) and therefore difficult planning of JIT-deliveries.

Fig. 1 Draft of the Mobile Factory concept (1. delivery via ship or truck, 2. unload on-site, 3. setting up on-site, 4. setting up of process modules)

Mobile Factory Network (MFN) as a Network Oriented Business Model

The proposed concept of the mobile factory shows high potential for its use in the construction industry due to its flexibility and changeability. A prerequisite for a commercial use of the Mobile Factory is an accurate analysis of the requirements on the construction site. These requirements have to be collected and evaluated systematically. Following such a situation analysis, it is important to cluster the identified requirements and to derive standardized process modules that cover any possible application in its various configurations and combinations. This makes part of a research conducted already by the authors in a separate study.

The focus of this paper lies in the implementation and commercialization of the Mobile Factory concept from an organizational perspective. Starting from a defined pool of standardized and modular process modules, it is therefore necessary to search for network designs to organize the configuration, delivery and refitting of mobile factories and their components. There are conceivable two fundamentally different forms of commercial business models:

- Establishment of an *intra-corporate / in-house network of mobile factories* in large construction companies
- Establishment of *service companies* with a network of clients in the construction industry, (temporarily rent of the mobile factory).

Basically, it can be assumed that the first mentioned form of individual contractors will not be rentable, unless they are multinational construction companies with a wide range of applications. The concept therefore is more realistic in its application through a service company. This service company builds up a sufficient pool of standard containers in different sizes (20/40 feet), of standardized process modules and organizes then the configuration, deployment, return and refitting of mobile factories. This service is performed for a rental fee. The amount of the fee depends on the rental period, on the destination (transportation costs) as well as on the desired configuration and/or additional services (eg. training or personnel on site).

Fig. 2 schematically shows the structure of such a MFN and the typical procedure for configuring and renting of a mobile factory.

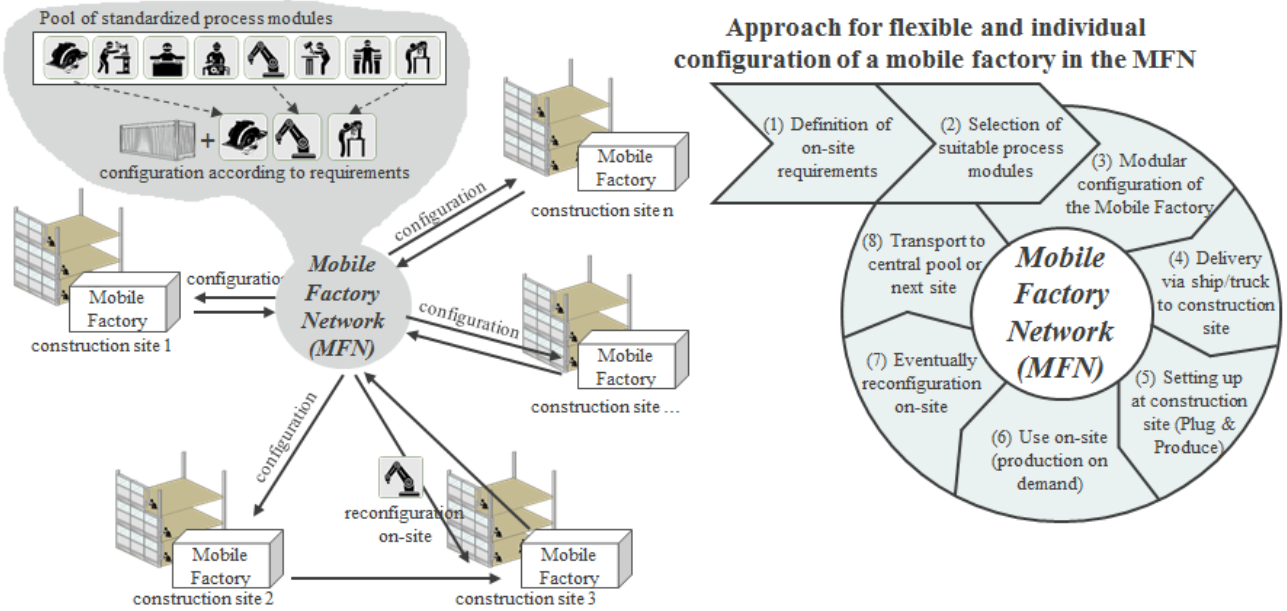

Fig. 2 Structure and configuration approach in the MFN

In a first step, the customer communicates the requirements of the mobile factory. Together with the MFN-consultant the appropriate process modules are selected for the described application. The mobile factory will be individually configured before it is delivered to the site by ship and/or truck in the fourth step. Once on-site, the mobile factory has to be set up easily, preparing the power supply

and making it ready for operation. Then, the mobile factory can be used by the employees on-site for specific manufacturing or assembly activities (JIT production on demand). If their occur changes of the requirements, additional process modules are delivered to the construction site and the mobile factory has to be reconfigured. After completion of the work, the mobile factory returns to the MFN-pool or will be brought to another construction site. When the mobile factory returns in the pool, the individual process modules are checked and if necessary repaired to ensure the next customer always a fully functional production unit.

Summary and Outlook

In this paper, the concept of mobile factories for the construction industry was briefly introduced. The advantages of this concept are various: long transports can be eliminated reducing the ecologic impact; parts for installation on-site can be produced JIT and on demand; reduction of organizational and planning effort for material logistics as well as reduction of buffer stocks at the fabrication shop and on-site. The paper presented also a service-oriented business model for the commercialization of mobile factories in the construction industry. Through the establishment of pools with highly standardized as well as flexible reconfigurable process modules the mobile factory can be configured individually satisfying the needs of every single customer or construction site.

Further research is necessary regarding the definition and the design of standard process modules that cover every possible requirement on-site. Under the acronym MOBIFAC (Mobile Factory), the Free University of Bolzano is engaged together with industrial partners in the development of a template model for a mobile on-site factory in the construction industry. The research team works once on the design of the production system and at the other side on the design of suitable business models for a commercialization of the mobile factory concept.

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