DEVELOPMENT PATH FOR INDUSTRIAL ENTERPRISES TOWARDS URBAN MANUFACTURING

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Abstract
Industrial enterprises are forced to cope with ever higher challenges resulting from trends like the ongoing individualization tendency which results in ever smaller lot sizes, like the limited availability of talents, and like the pressure towards ever lower emissions. A promising approach to cope with the increasing challenges is the application of new production strategies like urban manufacturing. In this contribution, a development path for companies to guide the transition towards urban manufacturing is presented. The development path is structured in seven essential perspectives which are split into five stages. Based on an as-is analysis, the starting point for the advancement of a company can be determined in the resulting raster, and consequently steps for the advancement of the company can be identified.

Keywords:
urban manufacturing; production strategies; competitiveness; transition path

1 INTRODUCTION
Based on the ongoing trend towards an individualization of products, Industrial enterprises are faced with ever smaller lot sizes and a very high number of variants in final assembly of customer-specific products. On the other hand, in some countries as Germany, a lack of qualified personnel, especially in rural areas can be stated.

A promising approach to cope with the challenges for industrial enterprises is to question their way of production, thereby differentiating between customer-neutral manufacturing and customer-specific individualization, i.e. in final assembly. Therefore, an approach could be to keep centralized manufacturing of customer-neutral pre-products and to decentralize the customer-specific production steps, e.g. final assembly, into smaller units which are close to the customers and near to hubs of qualified personnel, like in urban surroundings. To support companies in the transition towards the resulting urban manufacturing, in this contribution, a development path is introduced. For this, at first urban manufacturing is characterized, then the concept of development paths is highlighted. Based on this, perspectives for a development path towards urban manufacturing are described and a generic development path to support the respective transition is presented. The contribution ends with a summary and an outlook to future work.

2 URBAN MANUFACTURING
Urban manufacturing can be seen as an approach to tackle current challenges for industrial companies like the need for more flexibility and labour shortage [1]. In this contribution, we follow the view that urban manufacturing is a manufacturing approach, which is so compatible with its surroundings that it may even take place in urban surroundings and furthermore results in advantages for all related parties [2]. Thereby, its application area is especially products with a high degree of customization, a high ratio of value to volume, and which require knowledge-based processes in production. So, branches like heavy industries are not seen in the focus of urban manufacturing. Obviously, the request to be city-compatible results in demands on a factory, based on potential disadvantages of manufacturing in urban surroundings (cf. [1]).

An essential disadvantage of urban locations is the low availability of areas, which tend to be expensive. Consequently, to be city-compatible, factories have to have a low land consumption. This results in the demand for products with low dimensions, which are produced in low quantities and which have short dwell times in the site. Furthermore, to be city-compatible, manufacturing has to produce a low amount of emissions. In addition, as traffic is mostly heavy in cities, logistics should be low to keep the impact of the factory on the traffic volume low, thereby not worsening the traffic situation. Thereby logistics not only concerns the transport of goods, like material and products but also of humans, i.e. employees and customers.

Essential advantages of urban manufacturing are based on the premise that urban manufacturing results in short distances to the markets. Proximity to the resourcing market supports the collaboration and cooperation with suppliers for goods and services like research and development as well as training. Short distances to the output market reduce efforts for distribution logistics and facilitate the integration and bonding of customers.

Furthermore, short distances between housing and workplaces of employees support flexibility in working times and therefore in production capacity and work-life-integration.

3 CONCEPT OF A DEVELOPMENT PATH
Typically, companies will not realize urban manufacturing from scratch, but a respective transition process is needed. This process has to lead from individual starting points to company-specific target states. To guide the transition process, we suggest the concept of a generic development path which can be applied to different kinds of companies. Thereby, the development path considers essential perspectives of the development of a company towards urban manufacturing and is based on a set of development steps for the different perspectives. Interpreted as a process, the development may be run through completely from initial state to target state or in a company-specific range. By this interpretation of the term development path we follow the work of Lopez et al. [3] but are in contrast to Perkins and Small [4]. Lopez introduced a Digital Business Development Path to support companies in assessing their position related to digitalization. In this development path, the state of a company can be characterized by 5 perspectives with 6 development steps. Here, it is not needed that the steps have to be passed one after the other. Perkins and Small presented a Product Development Path for Microbial
4 DEVELOPMENT PATH FOR URBAN MANUFACTURING

4.1 Structure
The development path for urban manufacturing is structured into perspectives, covering essential characteristics: the factory (representing the overall manufacturing distribution approach), the product, manufacturing and its organization, sales, the human side consisting of employees and citizens as well as of the cooperation perspective. Therefore, in the development path emphasis is given to leveraging the advantages of urban manufacturing based on short distances to the output and resourcing markets as well as for the employees. Along the 7 perspectives, the development path is divided into 5 steps including the initial state and the target state, thereby following the most popular way of evaluating maturity as stated by de Bruin [5]. Obviously, besides the considered perspectives, other elements of the company and its processes like logistics, low-emission equipment, and IT-infrastructure have to be shaped in accordance to the state of the company, too. These elements are not directly considered in the development path as they are not seen as drivers for urban manufacturing, but enablers which have to be shaped based on the occurrence of the driving perspectives which are represented in the development path. Nevertheless, elements as logistics are of high importance for the city-compatibility of factories and should be shaped in a low-impact manner, e.g. by using electrically driven vans instead of heavy trucks for the case of logistics.

4.2 Factory
With the perspective factory, we refer to the manufacturing distribution approach including decentralization and number of factories as well as the respective work distribution between the sites.

The first characteristic in the perspective factory is the number of sites. In the classical manufacturing approach, we assume that manufacturing takes place in one central site, thereby leveraging economies-of-scale. The location of this site is typically selected without considering advantages of urban manufacturing but with traditional locational factor analysis. Therefore, the sites are often placed in more rural areas, and may be surrounded by cities over time. In these central sites, all organizational functions are bundled and products are entirely manufactured, also based on supplied components. The central sites are controlled in a centralized manner.

In the final state of the development path, the urban manufacturing state, we assume a decentralised approach, consisting of one or more pre-factories which are dedicated to manufacture customer-neutral pre-products, thereby still leveraging economies-of-scale and city factories, dedicated to the final manufacturing of customer-specific products, e.g. by configuration and final assembly. The manufacturing sites also contain indirect organizational units, e.g. for internal control and administration, but also for product development. In the case of city factories, product development focusses on localization of products towards regional needs and customer integration in engineering and innovation. The proximity of engineering and manufacturing also supports short feedback loops to advance products with regard to manufacturing, like manufacturability and quality issues. The distribution of organizational units for administration and control also enables a decentralized manufacturing planning and control approach, thereby reducing the complexity of managing the overall manufacturing network and its parts.

For the development path towards urban manufacturing, we suggest the following steps from classical factories to the decentralized urban manufacturing approach.

Initial State:
- classical factory for complete manufacturing, which is often in an initially rural area and is operated in a centralized manufacturing approach.

Step 1:
- establishment of a first city factory for final manufacturing of customer-specific products, thereby emphasizing on a specific urban area,
- core factory remains unchanged but is complemented by first city factory.

Step 2:
- establishment of further city factories,
- core factory remains unchanged but gets focus on manufacturing of pre-products, and is complemented by city factory.

Step 3:
- check if initial factory brings substantial market access, if not: question to transform it into pre-factory.

Final State:
- urban manufacturing by a decentralized manufacturing approach of one or more pre-factories for the manufacturing of customer-neutral pre-products and city factories for the final manufacturing of customer-specific final products.

Furthermore, it could be reasonable to decentralize also the innovation and engineering process as well as manufacturing control along the transition towards urban manufacturing. The product development-related area can thereby be seen as linked to customer-integration which is considered in the sales perspective, cf. chapter 4.5 and to its subject-matter the product, addressed in the following chapter 4.3. Manufacturing control is considered along with Industry 4.0 in the manufacturing perspective in chapter 4.4.

4.3 Product
Another essential base for a transition of the manufacturing approach in a company is the product itself, delivering possibilities and boundary conditions for manufacturing.
As stated in chapter 2, the development path for urban manufacturing especially addresses the manufacturing of discrete, complex series products with a high degree of customization, resulting in a high variety.

A significant property of the product with regard to the distribution of its production is its structure, i.e. in how far the product is composed from modules or single parts. Thereby, we assume for the initial state a classically developed product with no consideration of modularization, and for the final state a very high level of modularization of the products, which, in addition, are built on product platforms. Consequently, the following steps for the product perspective are suggested:

Initial State:
- classical product without modularization or platform consideration.

Step 1:
- first modules in a part of the products.

Step 2:
- cross-product platform/s.

Step 3:
- modularization of the full product range.

Final State:
- products, modules and platforms optimized for decentralized manufacturing with pre-factories and city factories, including late customization.

4.4 Manufacturing
To enable the envisaged decentralized manufacturing approach for customized products, classical production systems have to be transformed towards systems which enable the efficient manufacturing of very small lot sizes, i.e. down to lot size 1. This can be supported by applying lean approaches as well as by using technologies from the so-called Industry 4.0 [6], resulting in the following steps.

Initial State:
- classical manufacturing based on push principle.

Step 1:
- lean production with pull principle in sync with customer requests at city factory/factories.

Step 2:
- decentralized production triggered by customer orders at city factories which order components at pre-factory.

Step 3:
- manufacturing in lot size 1, enabled by Industry 4.0 to allow fine granular manufacturing control.

Final State:
- self-organization by products which are cyber-physical systems (CPS) that control their own flow through the overall manufacturing network as well as the manufacturing parameters.

4.5 Sales
An essential advantage of a manufacturing location for customized goods which is situated in an urban surrounding is its proximity to potential clients with the respective possibilities for customer integration. To leverage these possibilities, measures besides typical integration aspects like internet-enabled open innovation should be taken. These measures can range from face-to-face open innovation approaches to exploit customer ideas for designs and product solutions to the incorporation of customers in the actual manufacturing processes. Therefore, steps for the advancement towards leveraging the potentials of urban manufacturing can be the following:

Initial State:
- typical approaches for customer integration like internet-based open innovation.

Step 1:
- face-to-face open innovation by incorporating customers in idea development and problem-solving.

Step 2:
- integration of customers in indirect processes like product development, i.e. face-to-face co-creation.

Step 3:
- advancing the transparency of the factory by providing customers access to the production of their personal products, potentially including manufacturing and quality data.

Final State:
- opening the factory by integration of customers also in direct processes, e.g. by incorporating them in the final assembly of their personal products.

Reason for doing customer involvement in early phases of product creation earlier than in later phases is that in these phases, a one-way information flow from customer to company can be established. In contrast, by incorporating externals like customers in later phases of the product creation, also insight in these value adding processes is provided – which is an approach that may be seen as critical by the company at first.

4.6 Employees
To leverage the potential to increase the flexibility of working hours and of production capacity based on the possibly short distances between housings and workplace, which may be accompanied with short transfer times, new working-time models can be applied. This may range to a very high short-term flexibility based on self-organization approaches like KapaFlexcy [7] which may result in new levels of work-life-integration, too. So, potential steps for the transition are:

Initial State:
- rigid working-time model.

Step 1:
- flex-time model, especially for indirect employees.

Step 2:
- (multi-)annual working time accounts.

Step 3:
- participative working time planning.

Final State:
- self-organization of working times.

Besides this flexibility-oriented perspective, depending on the company-case, an increase of the degree of employee participation may be reasonable but is not mandatory for urban manufacturing but desirable.

4.7 Citizens
Seeing a factory as integral part of a city, which in the best case acts as a “friendly neighbour”, the relation between the factory and its neighbours, i.e. the citizens of the city, can be seen as crucial. Therefore, a perspective to present the relation between the factory and the citizens is suggested. Presentations for this feature may range from no active relation management up to an open factory, which is not only participatively planned but which offers
its infrastructure partly or as a whole to the public. Whereby the opening of the infrastructure as a whole may be difficult and even unachievable, the opening of parts could concern parking areas, canteens or day-care centres, so low critical areas, to externals. This results in the following steps for the perspective of the citizens of the development path:

Initial State:
- no specific relation-oriented measures towards citizens.

Step 1:
- provision of information about the factory, its state or future, to citizens.

Step 2:
- information exchange and citizen involvement by events like workshops.

Step 3:
- participative planning of the factory and its further development by incorporating citizens.

Final State:
- open factory which allows the usage of infrastructure, partly or fully, to externals, especially citizens.

4.8 Cooperation

The proximity to suppliers supports a close cooperation between the companies. This relates not only to suppliers of goods like material and components, but also of services. The mode of operation for this perspective may range from the classical supplier-client approach up to an integrated planning and operation of the supply chain including strategies, capacities and inventories in the sense of an Extended Enterprise as presented by Dold et al. [8] among others. Therefore, potential steps along the development path are the following:

Initial State:
- classical supplier-client relations.

Step 1:
- dedicated identification of local suppliers nearby the factory and begin of respective relations for sourcing.

Step 2:
- sharing of forecast and inventory level, supported by linked IT-systems.

Step 3:
- collaborative planning of the overall supply chain, thereby ensuring a global optimum in performance instead of local optimizations.

Final State:
- integrated management of the supply chain.

5 APPLICATION OF THE DEVELOPMENT PATH

The presented development path has the objective to support the transition of a manufacturing enterprise by guiding it towards the vision of an urban manufacturing through the identification of possible next steps for advancement. Thereby, the company may decide the actual target state, which is not necessarily the long-term oriented characterisation of the perspectives of the final states, but company-specific.

The application of the development starts with an as-is analysis resulting in a classification of the company in the states of the development path. Each of the states identified shows the option of a next step for advancement of the company towards its goal by examining the difference between the current state and the next step or state in the development path.

Figure 1 shows the example of a company which produces design-oriented, complex series products with a high amount of customisation. Thereby, starting points for the advancement are marked in green, intended target states in red. The promising next steps for the advancement of the company along the perspectives of the development path are identified as follows.

Concerning the factory and overall manufacturing approach, the current state at the company is the manufacturing at one central, classical factory. The company intends to open city factories to get better access to the output markets but would continue to manufacture final products at the core factory in future, too, if this is reasonable – as shown by the intended target state. In accordance to the development path, the next step can be to create a first city factory to complement the existing factory and to gain first experiences in manufacturing in urban surroundings, while already addressing one dedicated market.

The products of the company are already composed out of first modules, whereby the intention is to introduce cross-product platforms in addition. At the same time, these gaps also represent the next step to be done for advancement with regard to the product.

For the perspective manufacturing, the as-is analysis resulted in a classification in the lean production-state. As objective the company identified to apply approaches and technologies of Industry 4.0 to support the manufacturing in lot size 1 with innovative information technology. Therefore, the next step can be to realize decentral manufacturing, triggered by customer orders, thereby controlling the manufacturing in the system resulting from the establishment of an complementary city factory besides the original core factory.

Concerning sales, the company currently uses typical approaches and want to reach a state with high customer involvement including a transparent factory which enables customers to visit the factory and regard the manufacturing of its product, including the availability of manufacturing- and quality-related data. For this, the development path suggests as a next step, to start with customer involvement in local open innovation processes to address issues like design and the solution of customers’ problems.

As shown in the figure, the company currently applies a flex-time model for the working time of the employees where possible and wants to remain at this level. Therefore, no steps for advancement are needed for the perspective employees. Besides, it may be questioned if even if the working time model remains unchanged, if the degree of employee participation is advanced.

In the as-is state, the company has a one-way communication behaviour towards the citizens, e.g. by press releases, information meetings or open days. For the perspective citizen, an information exchange was determined. So, the establishment of events for information exchange is a potential next step for advancement.

For the cooperation perspective, the as-is state of the company is based on classical supplier-client relations. The aim of the company is to source locally at suppliers but not to advance the supply chain by integration or joint activities. Therefore, a potential next step is to identify nearby to suppliers and to start the respective sourcing.

The application of the development path should not be once, but in the long-term on a regular base. Thereby, the actual achievements may be compared with the defined objectives and the objectives may be verified and adopted where needed.
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<th>Perspective</th>
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<th>Step 1</th>
<th>Step 2</th>
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<th>Final state</th>
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<td>first city factory, core factory focus on pre-products</td>
<td>question to transform core factory into pre-factory</td>
<td>pre-factory/ies and city factories</td>
<td></td>
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<tr>
<td>Product</td>
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<td>first modules</td>
<td>cross-product platform/s</td>
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<td>Cooperation</td>
<td>classical supplier-client relations</td>
<td>local suppliers</td>
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Figure 1. Example of the application of the development path.

6 SUMMARY AND OUTLOOK
Companies face ever higher challenges based on trends like product individualization and talent shortage. A promising strategy to cope with the challenges is the implementation of an overall manufacturing approach, which is based on a decentralization of manufacturing into pre-factories and city factories. In this context, pre-factories are intended to manufacture customer-neutral components at economies-of-scale, and city factories are responsible for steps of product creation which are customer-specific – so an approach based on a partitioning by means of the customer decoupling point of order fulfilment. To support the transition of classical manufacturing companies into this decentralised “urban manufacturing” approach, a generic development path is suggested in this contribution.

The development path for the transition towards the urban manufacturing approach is divided into thematic perspectives and development steps. The perspectives of the development path are based on drivers of urban manufacturing. In the contribution, the following perspectives are suggested:

- factory, which also represents the overall manufacturing distribution approach,
- product,
- manufacturing and its organization,
- sales,
- employees,
- citizens, as well as cooperation.

Besides these perspectives, other factors are important for the realization of an urban manufacturing approach, too. Among others, this refers to logistics, low-emission equipment and machinery as well as to the information technology. These factors have to be realized in a manner, which fits to the requirements of the company in its respective state and which supports the city-compatibility of the site.

As next steps, the development path will be advanced based on discussions and expert talks with the scientific community before first tests in company applications will be done. The tests will serve for the further development and detailing of the path.

7 REFERENCES


