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Characterizing urban factories by their value chain: a first step towards more sustainability in production

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Abstract

Urban factories seem to be a promising approach to satisfy the needs of a population in urban areas and to create a close proximity with local stakeholders (customers, workforce, potential service suppliers, etc.). This paper presents a state of the art on urban factories to explore the various definitions of the concept and to identify the current gaps in the literature. Indeed, various types of urban factories have been characterized with various levels of urbanity, motivations and value chains. From this review, the authors propose a new typology of urban factories with different value chain profiles. This would be the initial step for implementing urban factories at the product and process design stage according to the profile of the value chain. The outcomes of this study are a list of definitions and case studies that will help cover the literature gap, and a preliminary projection into the design level. The discussion highlights the advantages and challenges of urban factories, and explores the sustainability aspect in the presented typology. The emergence of this type of urban factories requires both investment in innovative mobility and construction concepts, and the city's administrative support.

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Keywords: urban factory; urban manufacturing; sustainability; value chain

As the impacts of factories on the environment have become an important concern in the mid-20th century, factories have been pushed outside urban areas despite the integration of preventative environmental strategies to the factory's continuous functions and products [1]. This delocalization has also been the result of an ongoing societal and spatial changes in urban areas [2]. In addition, globalization has emerged to offer companies with countless improvement opportunities such as the lower factor costs in developing countries where factories could be implemented to serve the needs of high cost countries [3]. This leads to non-value adding impacts on the environment as a result to the expanded transportation flows including freight transportation which accounted for 45% of the total transport energy demand in 2009 [4]. These environmental impacts could be reduced by producing in close proximity to

consumers in a decentralized way [2]. In this perspective and considering that more than half of the global population lives inside urban areas, this close-to-consumer model should be designed for urban areas. However, polluting and noisy manufacturing functions have refrained factories from reintegrating urban areas. Today, this could be overcome thanks to the emergence of more energy and resource efficient production technologies, alongside with sustainable business models [2]. These possibilities have pushed researchers to introduce the concept of urban factories.

This paper presents an overview of the state-of-the-art on urban factories throughout the years and over different disciplines to present a unique typology of urban factories as a contribution to cover the gap in the literature regarding the lack of consensus in the definition of this key concept as presented

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in Section 3. In addition, this typology is presented to give a concrete hypothesis for the next steps in this research project, and a first set of concepts that will help differentiate the main methodologies to design the processes and the products of an urban factory for decision makers as presented in Section 4. This new typology has been projected on various case studies, and has been discussed with results from past papers to prove the positive relationship between the level of urbanity of a factory and its sustainability. This typology will both serve as a reference for definition, and the initial step for characterizing urban factories for designers according to the profile of the value chain they are dealing with. In Section 5, we discuss the sustainability aspect of urban factories and how it can vary both positively and negatively on each type. Finally, Section 6 provides a conclusion and future research opportunities.

1. Methodology

A literature review has been conducted on the concept of urban factories, and urban manufacturing in general. This has been conducted in two steps: firstly, the state-of-the-art of “urban” and “factory” separately, then both concepts together. In addition, a rigorous search using only “urban factory” was also conducted to analyze the harmony in the definitions in the literature. A cross-analysis of these various definitions has been conducted to extract all similarities and variations according to the context of each study. The results of this step were presented in sections 3.3 and 4.1 of this paper, and have led to the introduction of a new set of definitions according to the level of urbanity of the factory’s value chain. For this matter, the Porter’s value chain model was used since it covers all activities performed by a factory to create value taking into account inputs, processes, outputs, and support activities [5]. To bring a clear understanding of the proposed typology, various case studies of each type of urban factory have been presented in section 4.3. The presented classification has been based on the evaluation basis of life cycle assessment to highlight the importance of the urbanity of each key activity of the value chain in the achievement of an ideal sustainable model for manufacturing sites being closer to key activity sites. This has been discussed with results from previous case studies regarding pros and cons of urban factories while considering the projection of the profiles of urban factories on the proposed typology. Finally, the key conclusions from this discussion and the previous state-of-the-art were presented in section 4.

2. State-of-the-art of urban factories

2.1. The “urban” concept

An urban area can be defined as a continuously built up land mass of urban development that are within a labor market [6]. As this definition might seem a bit vague, it provides the main criteria to consider but not the quantitative scale. For this matter, the Population division of the United Nations Department of Economic and Social Affairs have suggested to follow each country’s definition separately as defined by the national statistical office [7]. For instance, the French National

Institute for Statistics and Economic Studies has defined an urban area as a group of touching municipalities, without landlocked lands, encompassing an urban center providing at least 10,000 jobs, and by rural districts or an urban periphery among which at least 40% of employed resident population works in the center or in the municipalities attracted by this center [8]. A more general delimitation method based mainly on population density has been introduced by the by the European Commission and the Organization for Economic Co-operation and Development (OECD) [9]. This lack of consensus has once been raised by Vlahov & Galea [10] suggesting that the lack of a uniform definition may hinder investigation of what is unique in urban areas [10]. More complexity can be observed when expanding the scope to include different degrees of urbanity, which once again are defined nationwide.

2.2. The “factory” concept

As defined in the CIRP Encyclopedia, a factory is a “(...) local grouping of production factors for the realization of the entire or a part of the value chain of real goods” [11]. This definition highlights the core function being manufacturing as it has shifted from craft production in small workshops to factories (formerly known as “manufactories”) in the middle of the 18th century due to technological advancement and productivity improvement [1, 12]. Factories started leveraging their industrial performance after the appearance of steam and internal combustion engines in the middle of the 19th century which has marked the first industrial industry, then the appearance of mass production [1, 13]. Unlike terms related to urbanity, the definition of “factory” has been presented in a congruous manner [4]. In its activity of value creation, a factory transforms materials, energy, and information into products, by-products, waste and emissions [14]. Despite this common concept, each factory is distinctive in its design and organization. This is mainly due to the existence of many influencing parameters as summed up by Wiendahl et al. [15] in the following ten parameters: Planning and control; Processes; Supply market; Markets products; Finance and economy; Law regulations; Work force; Resource efficiency; Material flow; and Facilities. According to Wiendahl et al. [15], facilities are arranged as core and support functions distinguished by their size, weight, and energy consumption [15]. Core functions being those of manufacturing and assembly, and support functions those of stocking, transporting, and information communications [11, 15]. These functions are organized in a way to determine the hierarchy of the factory, the quality standards, and finally the responsibilities assignment to the employees according to their qualification levels [11, 15]. In their study on factory buildings, Reichardt & Wiendahl [16] have presented the common forms of production buildings whose main function is to protect from undesirable events, and increase the processes’ performance by providing convenient work conditions and utilizing space [11, 15, 16]. In a broader context, a supply-chain has been defined in the APICS dictionary as “(...) the global network used to deliver products and services from raw materials to end

customers through an engineered flow of information, physical goods, and cash” [17].

2.3. The “urban factory” concept

Publications by researchers working in the Urban Factory research project in the Technical University of Braunschweig have defined the urban factory as “(...) a factory situated in an urban environment” [18]. During the second meeting of the collaborative working group of this project, the definition of an urban factory has been detailed by explicitly including the functions of utilizing the local characteristics of the urban surrounding, and creating products targeted at the local market while allowing the inclusion of customers in the value creation [1, 19]. It also utilizes proximity by reducing separation between the workplace and residence for urban factory workers [20]. These definitions are more focused on production factors than other definitions given by researchers in architecture and urban design. For instance, architectural researchers working in the Vertical Urban Factory project have limited their definition to the presence of the factory inside an city, and were more interested in exploring the building’s design as a vertical structure hosting either one or multiple factories with physical flows moving from top to bottom and vice versa [21]. In the same context, the architecture of an urban factory was then reimaged as a place where customers have to ability to design and produce a customized product inside an urban area [22]. This customer’s involvement during value creation has also been raised by researchers at the CHARLOT project around smart urban factories where the main objective is to allow customers to monitor their products virtually [23]. As a result, production will become decentralized and variable rather than centralized and limited [1]. Other studies in social science topics have implicitly defined urban factories as a factory inside an urban area [24, 25].

3. Proposal of a typology of urban factories

The literature review enabled identification of various uses of “urban factory” with different definitions.

3.1. Literature review results and new definitions

The common aspect among all previous definitions is the presence of the factory in the urban area with the manufacturing activity being conducted locally. This minimalistic scope is synonym of what could be found in the literature as “urban manufacturing” or “urban production” which focus on the reintroduction of manufacturing into urban areas [26]. This concept is limited in a way that it does not include in its core the interactions of the production factors with the urban environment. In this study, the urban presence of the factory as a production site is one of the main defining aspects of an urban factory. Some factories are unintentionally urban factories either as a result to the city’s growth into their previously non-urban area [2]. This joins the claims of Kaup [26] where he stated that some factories just happen to be located within the city but that doesn’t make them urban factories [27]. An urban factory should utilize its location and this aspect has remained

historically consistent in research projects of 1993 and those of 2021 [1, 20, 27]. The city-factory-product nexus presented by Herrmann et al. [28] shows the importance of the interdependencies between the city, the factory, and the manufactured products as all three are required for a positive urban value creation. The main relationships between these three are the utilization and the important exchanges that can keep this “ecosystem” stable which are mainly the urban needs fulfilled by the products manufactured by the factory, and the urban resources required from the factory [28]. Based on this city-factory-product nexus, and the presented state-of-the-art, this paper presents the following typology as a new definition to an urban factory:

- Full urban factory: a factory located inside an urban area, with its inputs (materials, employees...) being from the same urban area, and its outputs (products) being distributed in the same urban area. In this definition, the nexus is fully urban.
- Semi-urban factory: a factory located inside an urban area, with either its inbound or outbound logistics activities being conducted outside the same urban area. The nexus here is partly urban.

3.2. Porter’s value chain of urban factories

Utilizing urban surroundings has been the main differentiating aspect between an urban factory and a factory that happens to be inside an urban area. In our new definitions, we have mainly focused on the city-factory-product nexus, but it is necessary to include all activities conducted by the factory beyond the manufacturing and logistics activities. To do so, we have extended the scope of the investigation into analyzing the whole value chain which has been defined as “the full range of activities which are required to bring a product or service from conception, through the different phases of production” [29]. It mainly focuses on the created value which is the main role of a factory [11]. In this perspective, Porter’s value chain model will be used to schematize factories as presented in Fig. 1 in a multidisciplinary approach complementing the cross-cutting demonstration presented by Abdoli et al. [30] to determine which factors define an urban factory, and what factors are positively or negatively influenced by the urban presence [30]. This will allow us to identify and define the main types of urban factories as illustrated in Fig. 1 for which characterizations will be required. In addition to those, urban manufacturing sites have been considered at this step to serve as a reference for further comparisons.

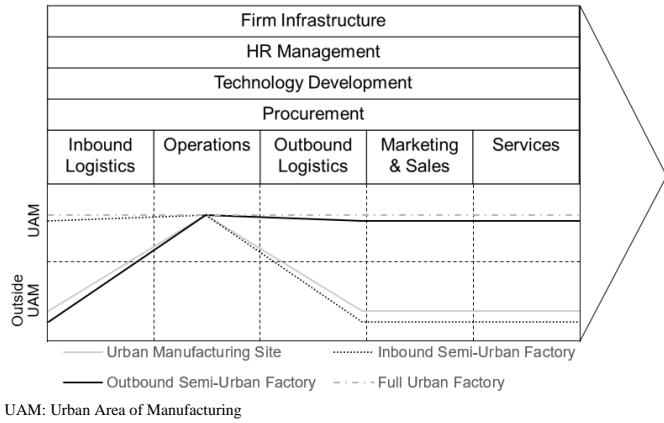


Fig. 1: Main concepts of urban production value chains.

This typology will also enable to evaluate the performance and the sustainability of urban factories according to the level of urbanity of their main functions in the future.

3.3. Case studies

Urban manufacturing site: A factory located inside an urban area with both its inbound and outbound logistics activities being conducted outside the same urban area. This category is mainly represented by unintentional urban factories as presented by Kreuz et al. [2] and Kaup [27]. This type of urban production can be observed in Fig. 2 representing a case study on eye glass frames conducted by Juraschek et al. [4]. In an initial scenario, raw materials are supplied globally then the final products are manufactured in China. The urban manufacturing requires production to be conducted inside an urban area according to the Chinese definition of the latest. The frames are then sent to Australia to be marketed inside the Sydney urban area. Many transportation flows between different areas are taking place to create value and deliver the final product to the urban population in Sydney that will use the final product.

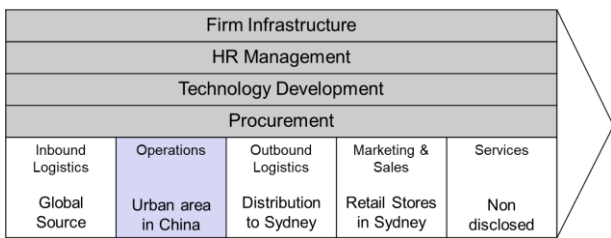


Fig. 2: Value chain model of the urban manufacturing case study.

Inbound Semi-Urban Factory: This type of urban factory utilizes local urban characteristics in its inbound logistics through supplying its main raw materials inside the same urban area where manufacturing is conducted. This includes factories implemented in urban areas known for specific materials such as “We Are The New Farmers” [31], a project indexed in the “Made In NYC” initiative portfolio presented by Tsui et al. [26] as a mini-factory that produces spirulina supplements, inside the urban area of Brooklyn, from the micro-algae grown locally inside the same urban area. As represented in Fig. 4, distribution is then conducted nationwide in the USA. This type of semi-urban factories can also include urban manufacturing

sites transforming urban waste into value-added products destined to be distributed to other urban areas.

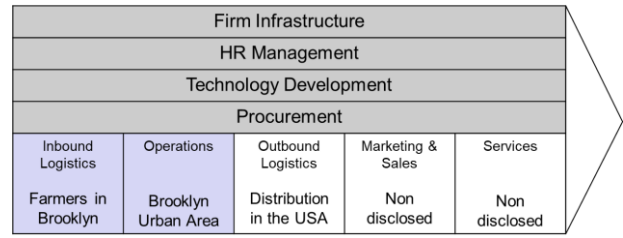


Fig. 3: Value chain model of the inbound semi-urban factory case study.

Outbound Semi-Urban Factory: Urban utilization in this type of urban factories happens only in its outbound logistics by basing their manufacturing activities specially for the urban area in which they are implemented. In these factories, the urban population’s needs pull operations activities design, whereas inbound logistics are conducted on other areas. Fig. 4 represents a case study for this would be “FabUnit” [32] in the urban area of Crest in France in which regional recovery centers, NGOs, and plastic industrials supply the urban manufacturing facility with raw materials (mainly plastic and wood waste) that are transformed to furniture which is distributed inside the Crest urban area.

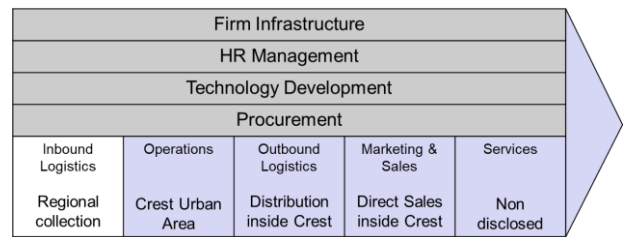


Fig. 4: Value chain model of the inbound semi-urban factory case study.

Full Urban Factory: This type of urban factory represents the ideal utilization case where local urban resources will be transformed in the same urban area into products destined for local use and consumption. It resembles a geographical closed-loop of value creation inside one urban area. An example to that is the “Textile (Life)Cycling” project [33] conducted by “ReFlow” in which textiles are collected inside the urban area of Amsterdam, as represented in Fig. 5, to be either refurbished or recycled into products and materials intended to be distributed and used inside the same urban area.



Fig. 5: Value chain model of the full urban factory case study.

3.4. A first step to design urban factories

To provide factory designers with a clear outline to design an urban factory, it is important start with the positioning of the type of urban factory. Since the factory's urban presence is the only determining factor for what an urban manufacturing site is, its urbanity can be a result of a facility location optimization problem for a future implementation to separate the hypothesis of historic presence. Regarding urban factories, three choices are possible as presented in Fig. 6.

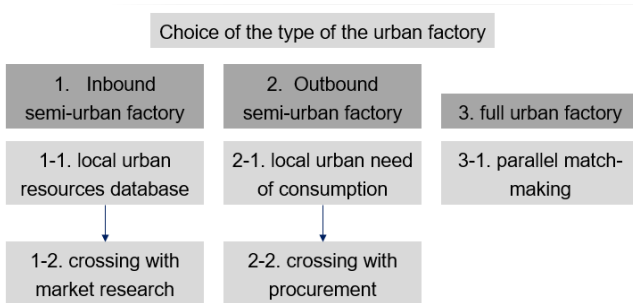


Fig. 6: First steps in urban factory design.

To design the outbound semi-urban factory in which the main driver is to respond to a local urban need, a methodology has been presented in [29] where the first step is to investigate the needs of the urban consumers (2-1), then the feasibility is evaluated by through a cross-analysis at the procurement level to assess the availability of the needed resources and what needs to be imported from other areas (2-2) [20]. The inbound semi-urban factory has a similar approach in its design, but instead of having needs as inputs and bills of materials as outputs, its first step (1-1) requires data on the available local resources (materials, labor, infrastructure...). This data will then be cross-analyzed with what is needed globally following the product design team's procedures (1-2). Finally, for the full urban factory, a parallel match-making (3-1) is conducted as presented in [34] where the potential exchanges between the factory and the urban area are crossed with a list of possible methods and measures that can allow the fulfillment of local needs using local resources [34].

4. Discussion

The partitioning of the value chain into activities has allowed to visualize the various types of urban factories presented in the literature and to distinguish each type from another. As stated previously, this serves as the initial step of identifying the type of urban factory to characterize at the design level as a clear differentiation can be observed in Section 4.4. It allows manufacturers track the robustness of their supply chains depending on how decentralized their activities can become. This decentralization in urban areas reduces the level of dependency on global supply chains, making urban factories more resilient to worldwide incidents and pandemics [1, 26]. In a comparative LCA study of urban and non-urban produced goods, Juraschek et al. [4] have simulated 4 value chain scenarios for the manufacturing of the

same product for the same urban consumption location. The difference between all 4 scenarios is the level of urbanity of the value chain. The more activities were conducted in the same urban area, the less environmental impacts were generated [4]. Projecting these results on the typology presented by this paper, a preliminary ranking according to environmental impact can be deduced placing the full urban factory as the eco-friendliest. Customizability has been a dominating aspect at full urban factories and has been deemed as an enabler to lower environmental impacts and costs [1]. Although proximity with different value chain key stakeholders results in less transportation and distribution impacts, it can also result in more human health and urban ecosystem impacts due to the small propagation distance. This multicriteria problem should be investigated and analyzed before drawing a rank between the presented types of urban factories. Worker satisfaction is an advantage of urban factories, and full urban factories will lead to more satisfaction if non-urban activities can be reduced [35]. Regarding urban inbound and outbound logistics, despite the attractiveness of the short distribution channels, urban factories might face difficulties during deliveries due to urban restrictions [36]. These restrictions can also affect the choice of used technologies and engines, and the space of implementation of the factory. Many of these challenges can be overcome through innovative mobility concepts, adaptability, area utilization, and design concepts [36]. Many cities, like Barcelona in 2014, have started to encourage the implementation of urban factories to produce goods destined to be consumed by the local population [1].

5. Conclusion

Different types of urban manufacturing have been studied throughout the last ten years with different degrees of urbanity in the main activities they conduct to create value. This diversity has led scientists to create an involuntary disagreement regarding the definition of an urban factory in which the macroscopic views on the value chains were divergent. This paper has explored these different variations of and has presented a new typology of urban factories uncovering the main key findings in the state-of-the-art presented in section 3. This classification divides two main types of urban factories: semi-urban factories (both inbound and outbound), and full urban factories. These types of urban factories have been presented and represented with case studies alongside the concept of the urban manufacturing site which represents an unintentional form of an urban factory in which no considerable location utilization can be observed in its value chain. Although a quick view on these types might have led to think that full urban factories are the most sustainable, these might create more challenges in term of overcoming urban restrictions in more levels and activities of the value chain resulting in less performance and more costs. The emergence of this type of urban factories requires both investment in innovative mobility and construction concepts, and the city's administrative support. Finally, the presented typology serves as an initial step in characterizing multipurpose urban factories at the design stage which is the positioning since each type will

be characterized differently according to the urban activities that are conducted locally.

The next steps in this research project will be to characterize urban factories based on case studies and literature, then to validate the presented typology. A tool will then be designed to analyze urban factories and their impacts based on Porter's value chain model and life cycle models. Finally, all these outcomes will be applied on the field to study the practical feasibility, and the main findings will be shared.

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