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# Small-scale Production Sites as Part of Urban Resilience Infrastructure: The Intersections of Urban Planning and the Fab City

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## 1 ABSTRACT

Research in the wake of recent international crises points to the potential of urban production, particularly small-scale, accessible, digital production sites such as Fab Labs and makerspaces, to strengthen cities' resilience by contributing to faster response times in the development and creation of innovative products and to knowledge-sharing and skills development for local communities (HILDEBRANDT et al. 2022). This has been recognized by a growing group of cities who have joined the Fab City Global Initiative, which now includes 52 members (FAB CITY FOUNDATION). The Initiative envisions a future of almost completely local and circular production, as part of a globally connected and mutually collaborative distributed production network (DIEZ 2016). At the same time, cities are facing an overall long-term trend in which productive uses are disappearing from the inner-city and being pushed to the peripheries (BENKE 2021; DE BOECK/RYCKEWAERT 2020; HATUKA/BEN-JOSEPH 2022; JURASCHEK 2022; NOVY 2022). This is continuing despite – and, in some cases, even driven by – cities' strategies to encourage sustainable urban development and the adoption of guiding principles for urban planning such as mixed-use zoning, the 15-minute City, etc. (BRANDT et al. 2018; LIBBE/WAGNER-ENDRES 2019; RYCKEWAERT et al 2021; SCHROCK/WOLF-POWERS 2019).

The current number and scale of small, accessible, digital production sites like Fab Labs is still inadequate to meet the needs of the Fab City vision and to fulfill the potential for significant impact on cities' resilience (HILDEBRANDT et al. 2022). Expansion of these sites is made more difficult by the high competition with other uses for exactly the type of central and accessible spaces that small production sites need (DE BOECK/RYCKEWAERT 2020; LIBBE/WAGNER-ENDRES 2019). A product of the project "Fab City: Decentral, digital production for value creation" (funded by dtec.bw, NextGenerationEU), this paper links these challenges with the role of urban planning in the integration of small production sites in the existing urban fabric. Drawing on the literature and discourse on urban production, as well as interviews and observations of OpenLabs set up in Hamburg in the Fab City project and case reports on other small digital production sites, we elaborate a set of factors of urban integration for these sites. We then propose key areas in which further research is needed in order to develop or adapt planning instruments and policies to support the incorporation of these forms of production as part of the resilience infrastructure of urban neighborhoods.

Keywords: Fab Lab, Fab City, planning, urban production, urban resilience

## 2 INTRODUCTION

The past years have brought with them several crisis events which have demonstrated the fragility of global logistics networks and have highlighted the precarious nature of cities' reliance on them. These range from shipping accidents and escalating violence around the Suez Canal, to the Russian war in Ukraine, to the Covid-19 pandemic. In all cases, wide-ranging impacts on trade have been observed and have had repercussions for cities and their residents as demand for certain goods and materials have changed at the same time that availability and costs have fluctuated. The discourse on urban resilience emphasizes the need for cities to strategically consider these and other hazards and to develop new infrastrutures, policies, networks, and transparent processes to respond to them (see e.g. MEEROW et al 2016; SHAMSUDDIN 2020; WARDEKKER 2021).

Rooted in an international network of Fab Labs which grew out of a project at MIT's Center for Bits and Atoms, the Fab City Global Initiative was founded with the goal of enlisting cities which pledge to work towards a transformation of their production and consumption systems "from 'Products In Trash Out' (PITO) to 'Data In Data Out' (DITO)" (DIEZ 2016; DIEZ et al 2019). Reslience is explicitly mentioned by the Fab City Initiative as a core goal for the Fab Cities, emphasizing the contribution of a strong focus on local business, workforce, and supply chain development towards combatting urban challenges such as climate change, impacts of globalization, etc. (DIEZ 2018). Barcelona became the first member in 2014 and is now joined by 37 other cities, eleven regions, two countries, and one island (FAB CITY FOUNDATION). Concrete commitments and strategies differ, however the members pledge to work towards the production of “(almost) all the energy, food and products they consume, to deploy circular economy strategies for the relocalisation of production, and the technological empowerment of citizens” by 2054 (FAB CITY GLOBAL INITIATIVE). Hamburg became the first German city in the initiative in 2019 (FAB CITY FOUNDATION; BEHÖRDE FÜR WIRTSCHAFT UND INNOVATION).

### 2.1 Small-scale, accessible, digital production

Fab Labs and makerspaces represent certain types of small-scale, accessible, digital fabrication sites, which have been recognized as a new form of production infrastructure in cities (MEYER/ESCH 2023). When discussing this model of production, terms such as makerspace, Fab Lab, hackerspace, repair café, etc. are used rather interchangeably. These are community workshops, open to the public (in some cases in exchange for a membership or usage fee), and providing access to digital production machinery such as 3D printers or CNC cutters, as well as some traditional tools like drills or sewing machines. They share the mission of supporting people to make things, whether out of necessity, as an educational project, as a business or product protoype, or ‘just for fun’ (CENERE 2021; DIEZ 2012; TROXLER 2016). Thus, they are part of Fab City’s envisioned distributed production network that cycles materials and products locally and regionally, while design data, skills, and knowledge are exchanged both locally and globally.The Fab City concept forsees the implementation of Fab Labs as physical spaces in urban neighborhoods which house citizens, business, research, educational efforts, etc. for the purpose of “social fabrication” as an integral part of the larger “fabrication ecosystem” (DIEZ 2012; DIEZ 2016).

Increasingly, these types of production sites are being discussed as potential contributors to urban resilience, whether in terms of sustainability, supply chain localization and responsiveness, community building, etc., but have not reached the scale and capacity needed to attain significant impacts (see e.g., HENNELLY et al. 2019; HILDEBRANDT et al. 2022; LÄPPLE 2016; MONACO/HERCE 2023; RUMPALA 2021; PEEK/STAM 2019). However, growth in the number and capacity of small-scale production sites in cities poses several challenges related to the physical, regulatory, and social frameworks within urban neighbourhoods (BENKE 2021; LIBBE/WAGNER-ENDRES 2019; SCHMITT et al. 2019; SCHONLAU et al. 2019; SCHREINER 2021).

This paper deals with these challenges at the intersection of urban planning and the integration of small-scale production. Our research has been enabled through the project “Fab City: Decentral, digital production for value creation” (funded by dtec.bw – Center for Digitalization and Technology of the German Federal Armed Forces, which is financed by the European Union – NextGenerationEU) under the leadership of the Helmut Schmidt University. Within this project, several OpenLabs have been established which house a range of productive approaches and focus on open source methods. Drawing on the literature and discourse on urban production, as well as interviews and observations of two OpenLabs in Hamburg and case reports on other small digital production sites, we propose a set of factors to describe the aspects of urban integration of these sites. We further explore the relevance of small-scale, accessible, digital production sites for urban resilience within Wardekker’s (2021) framings of Resilience Planning and Resilient Community Development. We then propose key areas in which further research is needed in order to develop or adapt planning instruments and policies to support the incorporation of these forms of production as part of the resilience infrastructure of urban neighborhoods.

## 3 URBAN PRODUCTION AND RESILIENCE

The achievement of broad Fab City goals will require production transformations at many different scales, both inside and across urban/regional boundaries. Within cities, the type and scale of production varies from individual creative work to traditional crafts to agriculture to heavy industry. The formal definition of urban production is under debate in the literature, along two core questions. First, researchers set different boundaries according to which context is sufficiently urban and how that can be determined (HAUSLEITNER et al. 2022; JURASCHEK 2022; PIEGELER/SPARS 2021; SCHMITT et al. 2019).

Second, they disagree about whether production should be limited to physical items or should include knowledge and services (BRANDT et al. 2017; DE BOECK/RYCKEWAERT 2020; GÄRTNER/SCHEPELMANN 2020; LIBBE/WAGNER-ENDRES 2019; PIEGELER/SPARS 2021; SCHMITT et al. 2019). We adopt the material understanding of urban production, as this best reflects the function of small-scale, accessible production sites as it relates to urban planning. That is, the fact that physical products are created at these sites, though in many cases alongside or in addition to knowledge production, separates them functionally from purely non-material productive uses in terms of regulation and management within urban planning.

While there are many theoretical approaches underlying the concept of urban resilience, for the purposes of this paper, we apply the definition suggested by Meerow et al. (2016, pp. 39):

"the ability of an urban system – and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales – to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity."

This definition highlights the interconnected and multi-scalar set of systems that are involved in considerations of urban resilience. In the context of urban production, this differentiation is significant, as scales, systems, and communities of production have changed over time. Especially in the context of the Fab City concept, the networks of production differ substantially from the status quo in terms of spatial scale. General discussions of urban production often link it to urban resilience in connection with sustainability: via socio-economic concerns such as retention of certain industries or workforce development, or within Circular Economy debates (see e.g. COSKUN et al. 2022; HAUSLEITNER et al. 2022; LIEDTKE/BÜTTGEN 2021; PEEK/STAM 2019; RAPPAPORT 2020; SCHONLAU et al. 2019). Local manufacturing and small-scale production, in particular, are emphasized as key actors supporting urban resilience through their production activities and knowledge generation but also as endangered members of the urban fabric, who are at risk from economic pressures and urban development changes (see e.g. BRANDT et al. 2018; HILDEBRANDT et al. 2022; MARTIN/GRODACH 2023; SCHROCK/WOLF-POWERS 2019).

In considering these conflicting positionings of urban production, Wardekker's (2021) additional framings of resilience are helpful, contrasting the perspectives of the systems approach with that of a community focus and combining this with the aspects of "equilibrium" versus "evolution." This results in four framings: Urban Shock-Proofing (systems + equilibrium), Resilience Planning (systems + evolution), Community Disaster Resilience (communities + equilibrium), and Resilient Community Development (communities + evolution) (WARDEKKER 2021). While discussions of urban production touch on all of these framings in different respects, the equilibrium perspective is more present, e.g. responses to disasters and shocks or reindustrialisation. The Fab City Initiative's goals imply, however, a fundamental disruption of the existing production and consumption systems which removes (almost) all extra- and interregional material and product flows and reimagines the role of citizens as prosumers (DIEZ 2012; UNTERFRAUENER et al. 2017).

This relies on a significant re-alignment towards digitally-supported production methods and a new, broader conceptualization of the actors in the production system, and it confronts the evolution perspective of resilience. One line of research into the Fab City and the Maker Movement can be grouped around this shift in the development of communities and networks of production (e.g. CENERE 2021; GARNIER/CAPDEVILA 2023; UNTERFRAUENER et al. 2017). The corresponding line of research takes a systems focus on what kinds of specific (co-)production infrastructure are demanded by a Fab City and how these can be envisioned in the urban space (e.g ELWAKIL et al. 2023; HENNELLY et al. 2019).

### 3.1 Urban planning and integration of production

We refer to the integration of urban production in terms of the implementation and embedding of a production site in a neighborhood in physical and social terms. Physically, urban integration includes land use and planning, local mobility, energy, digital, and other infrastructures, and materials. Socially, urban integration describes the bidirectional relationships of local, social, and economic structures and networks with the production site. It is similar to the concept of 'embeddedness' in some English-language studies (e.g. TSUI et al. 2021). Under the guiding principle of mixed-use planning adopted by the urban planning profession over the past 30 years (BBSR 2017), cities are attempting to reverse the dis-integration of urban spaces which happened as a result of the 20th Century planning philosophy of separation of uses and the implementation of strict land-use policies (RYCKEWAERT et al. 2021).

Detailed descriptions of the evolution of productive industry and manufacturing in cities historically can be found in the literature and from the Cities of Making project (e.g. CROXFORD et al. 2020; JURASCHEK 2022). The broad trend has seen the urban factories which arose as part of the inustrial revolution and traditional, local craft and manufacturing sites increasingly pushed to cities' peripheries by zoning and land-use regulations (DE BOECK/RYCKEWAERT 2020; HATUKA/BEN-JOSEPH 2022; JURASCHEK 2022). Despite this, studies show that industry and producers do prefer to locate in or near mixed-use areas with certain urban characteristics: for access to networks of other companies or producers in their field, better transportation infrastructure, better access to customers or for employees, etc. (BONNY 2021: GÄRTNER et al. 2021; HATUKA/BEN-JOSEPH 2022). Increasingly, the mutual benefits for industry and cities that stem from intentional cooperation around urban production are being recognized, as, for example, discussions of urban industrial symbiosis show (e.g. JURASCHEK 2022).

The movement towards mixed-use planning policy has been slow to yield measurable positive results for productive uses (BONNY 2021; PIEGELER/SPARS 2019). Mixed-use zones typically assign a certain percentage of area to different uses, however, in the German planning system, there is no specific usage category for production. Depending on the nature of the production, it might fall under commercial or industrial use categories. This means it is not possible to assign a certain amount of production to a mixed-use area, and that productive users then compete against other commerical or industrial users for these spaces (LIBBE/WAGNER-ENDRES 2019; SCHMITT et al. 2019). Frequently, formally exclusively industrially zoned areas are changed to mixed-use, but resulting development policy choices that prioritize higher profit residential and office uses lead to an overall decrease in the amount of space used for production (DE BOECK/RYCKEWAERT 2020; LIBBE/WAGNER-ENDRES 2019). Some describe this process as 'industrial gentrification,' in which productive uses experience the same spiral of rent and operational cost increases and eventual displacement as some poorer urban residents of newly fashionable neighborhoods (BRANDT et al. 2018; RYCKEWAERT et al. 2021; SCHROCK/WOLF-POWERS 2019).

Another issue limiting the expansion of production sites in mixed-use areas and their preservation in existing neighborhoods are conflicts that arise from noise, emissions, traffic generation, or other potential nuisances for the community. These nuisances are regulated within local zoning codes according to specific metrics, such as maximum decibel levels during daytime and nighttime. In existing neighborhoods, so-called 'NIMBY' (Not In My Backyard) movements can arise and drive an existing production site away or even prevent a productive use from entering the area through legal means (GÄRTNER/STEGMANN 2015). Residential concerns are usually prioritized for protection in these cases, which leads to an increased chance of displacment for production (BENKE 2021; SCHREINER 2021). There is a general lack of awareness of benefits or of active local proponents of production and, especially close to residential areas, a tendency of citizens and planners to fear potential conflicts (LIBBE/WAGNER-ENDRES 2019; SCHONLAU et al. 2019).

Small-scale, digital, accessible production sites such as Fab Labs and Makerspaces have been proposed as good practice examples of new urban production which can contribute to increased awareness among citizens and planners (LÄPPLE 2016). The digital production tools and methods they apply are less likely to cause a nuisance to the local community directly, although not all potential problems can be solved with technology. For example, traffic at the production site might still be a issue (BENKE 2021). Labs need to be consciously and conspicuously integrated into neighborhoods, though, in order to activate and engage the local community: residents, as well as building owners, local businesses, and social networks (SCHONLAU et al. 2019).

Still, not all labs or production sites have the same demands, and their thematic or technical focus impacts the extent to which physical, economic, and/or social aspects or networks are prioritized. Lange et al.'s (2016) survey of open workshops in Germany shows, for example, a higher level of local engagement in repair workshops compared to the city or even region-wide user-shed found in workshops focusing on new production. Further typologies of small-scale, accessible production sites also distiguish between their relationship to products and to community engagement. Hennelly et al. (2019) group several makerspaces in types along a spectrum from educational focus to operational productive focus and highlight tradeoffs, e.g.

agility or scale, that come with different foci operationally and in local networks. Capdevila (2017) differentiates between innovation spaces with specific topic specialization and without, ‘dirty’ vs ‘clean’ productive activity, and with “activist” identities or without them.

The type of site can also be determined by the materials in use and needed connections to material flows, with associated consequences for the type of space and location of the site that are typically observed (ELWAKIL et al. 2023). All of these studies touch upon the differences in the level of local community interaction and types of actors engaged that their different types imply. Most informative from a physical planning perspective, Elwakil et al. describe in greater detail the spatial context and built environment of their five types of makerspaces and mention important siting considerations such as transportation network access, connections to historical craft communities, or nexus points of different land uses. Table 1 summarizes Elwakil et al.’s types of makerspaces.

<table>
<tr><th>Type</th><th>Building type/use</th><th>Highly-frequented places?</th><th>Land use</th><th>Population density</th><th colspan="2">Further points</th></tr>
<tr><td>Reuse Makerspace</td><td>Stores, shops, markets</td><td>Yes</td><td>Residential-commercial nexus</td><td>Higher</td><td colspan="2">Public transit hubs close-by</td></tr>
<tr><td>Repair Makerspace</td><td>Public or non-profit spaces, also shops, garages, etc.</td><td>Yes</td><td>Residential-commercial nexus</td><td>Higher</td><td colspan="2">High diversity depending on service orientation (bottom-up café model vs “private repairers”)</td></tr>
<tr><td rowspan="2">Craft Makerspace</td><td>Small shop/café</td><td>Yes</td><td>Residential-commercial nexus or commercial</td><td>Higher</td><td>Social and productive aspects combined; target general public</td><td rowspan="2">Connection to history of craftsmanship in the local area</td></tr>
<tr><td>Larger workshop</td><td>No</td><td>Industrial</td><td>Lower</td><td>Need for larger tools or machines; target specialists</td></tr>
<tr><td>Fabrication Makerspace</td><td>Sharing educational or university spaces</td><td>No</td><td>Institutional or Industrial</td><td>Lower</td><td colspan="2">Open to public; Educational and training focus</td></tr>
<tr><td>Distribution Makerspace</td><td>Larger warehouse or sharing waste management spaces</td><td>No</td><td>Industrial or industrial-commercial nexus</td><td>Lower</td><td colspan="2">Roads and large vehicle access needed; collection, sorting, transfer of goods rather than production.</td></tr>
</table>

Table 1: Summary of Elwakil et al. ‘s (2023) makerspace typologies. Own illustration.

Each of these studies also emphasize the hybridity of their proposed typologies. The sites they investigated have, for the most part, characteristics of multiple types and the categories remain fuzzy, with different researchers using different characteristics to distinguish between types.

These discussions about urban production and about open production sites identify several points of thematic relevance to urban planning and urban development. Typologies and case studies of production sites reveal the high level of diversity among urban production and producers. By synthesizing these aspects into a set of factors, we aim to develop insights into the overlap of planning concerns and collaborative local production which can help inform efforts to expand small-scale, digital production in urban neighborhoods.

## 4 METHODOLOGY

To develop the factors of urban integration of small-scale, accessible, digital production sites, we performed an analysis of reports and studies on the operation and implementation of these sites. We relied on a snowballing method to compile a core set of studies, beginning with publications of the Fab City movement and related project reports and building onto this with searches in Google Scholar combining key terms from the literature around urban production and urban development with ‘Fab Lab’ and ‘makerspace.’ Searches were conducted with both English and German terms. The citations within the resulting texts and the sources which cited them were considered for inclusion in the inventory. Texts were selected that described the implementation or operation of a small-scale production site at a physical location or that described studies (surveys, interviews with staff or makers, etc.) of small-scale production sites at one or more locations. The key unifying element was the physical presence of the site as an operating productive use in a space dedicated to this purpose. Visioning or strategy processes and reports about the conceptual planning of potential future productive spaces or activities were not examined. Similarly, we excluded production activities held exclusively as part of temporary events (e.g. festivals) and mobile production units, as well as texts describing the development or protoyping of a single product or process rather than the site itself. Studies were also limited to those covering cases in urban planning contexts similar to Germany (Europe, UK, North America, Australia, etc.), excluding as well those that focused on informal settlements.

This search resulted in 21 texts, which underwent Qualitative Content Analysis (see, e.g. MAYRING 2000) using a combined deductive and inductive approach. The text included studies of German cases (5), European studies with single non-German cases or multiple cases (12), and international studies (4). Core themes of urban integration from the literature review of urban production and urban development discourses composed initial categories and sub-categories for coding. These categories were iteratively expanded as new topics arose out of the reviewed texts, and the coding of texts then validated again. The systematic analysis resulted in 70 initial factors, across seven thematic categories (space and location, planning instruments and structures, useage, infrastructures, networks and community, local economy, materials and waste). Two Fab City project OpenLabs, operational at dedicated sites in urban neighbourhoods in Hamburg, were also the subject of further first-hand observations. Both labs share a thematic focus on material circularity and development of circular business models:

- OpenLab_Textile, focusing on fabrics and clothing design and production, located in a former shop space in a commerical area along a pedestrianized street in the inner city.
- OpenLab_Plastic, focusing on production with recycled plastics, located in a building housing other productive uses in the inner periphery of the city and along a major road. The site is on the edge of an industrial area which borders areas with residential useage.

Drawing on insights gained through observations of the labs and interviews with lab management, the preliminary list of factors was synthesized into three types: operational factors (internal or management concerns), urban environmental factors (external, influencing the Labs but not significantly influenced by them), and integrative factors (bi-directional relationship to the labs). Factors related exclusively to operational concerns or management of labs or makerspaces were then excluded as they fall outside of the scope of urban integration. These constituted a large share of the preliminary list, as many studies discussed, for example, business models and interior design concerns of individual labs in detail.

## 5 FACTORS OF URBAN INTEGRATION

Table 2 presents the resulting list of 26 factors. They are divided into four thematic categories: built environment and physical space, local planning and useage, material and waste, and networks. These factors summarize the elements of urban integration discussed in case studies of productive makerspaces and labs across various contexts. In order to highlight the extent to which the production site has the potential to influence the factor, we further distingusísh between factors with exogenous and endogenous character.

The factors considered exogenous are those that the production site does not have the ability to influence directly and which, thus, act to some extent as determinants of the form and nature of the implementation and/or operation of the site. These are described in the reviewed cases often as criteria taken into account in siting and location choice by lab founders. The factors considered endogenous are those for which the research can already demonstrate potential for a bi-directional effect. This methodology does not reveal the character of the factors' impacts, whether positive or negative on the production site or the neighborhood. The elements that are more or less important for successful implementation differ according to the individual goals of lab founders or the operational framing of the production in terms of materials, target groups, etc. Although some insights can be drawn from the literature and local case studies, further research will be needed both to validate the factors in further cases and to elaborate the nature of their impacts.

Regarding the category of built environment and physical space, as observed in Hamburg and in the examined case studies, the production sites operate in existing buildings and neighborhoods at a scale too small to influence physical infrastructures. Within these limits of scale, though, highly visible presence of the site and open concepts of use of space (sharing) can have impacts on the use of space and the atmosphere of the street in a localized manner (MATTIOLI 2021; SCHONEBOOM 2018). The examined reports also demonstrate that founders search for certain context characteristics for their production sites, such as an industrial past (e.g. CENERE 2021; JOHNS/HALL 2020) or proximity to certain user groups, such as youth or entrepreneurs (e.g. MATTIOLI 2021). While current studies show a more reactive relationship of small-scale production sites to other factors in this category, e.g. costs of or demand for space as a driver of location choices, research into industrial and social gentrification processes implies potential for endogeneity. This could include, for example, the production site driving a change in the perception of the socio-economic character of the neighborhood, whether indirectly or as part of a concious development process or investment (see, e.g. SCHROCK/WOLF-POWERS 2019).

| Built environment and physical space | | |
|---|---|---|
| | Factor | Description |
| Exogenous | Availability of space | Availability of appropriate space for a lab that is also free in the desired time period |
| | Centrality of the location in the neighbourhood or city | Proximity to the centre / 'core' of the neighbourhood or highly frequented locations |
| | Built context and history of the site | Existence of a certain historical character, building types, or identity of the neighbourhood or location, e.g. craft or industry/warehouse district |
| | Infrastructure for transportation and mobility; Accessibility | Existence and quality of access to mobility infrastructure and services in and around the location for passenger and freight transport |
| Endogenous | Cost of the space | The costs of renting the space and/or other costs associated with the use of the premises |
| | Demand for space | The level of demand for appropriate spaces in the neighbourhood, e.g. competition |
| | External impact/visibility of the location or rooms | The impression of the lab from the outside, e.g. the ability to recognize it (signage, visibility in the streetscape, etc.) and to understand it passively (looking through windows into the lab, information about offers, etc.) |
| | Options for space sharing | Possibility of using the space/rooms of other institutions or organizations for a lab project or providing space in the lab for other users/initiatives |
| | Socio-economic context of the site | Existence of a certain socio-economic character or identity of the neighbourhood or location, e.g. population age or wealth, social disadvantage, etc. |
| Local planning and usage | | |
| | Factor | Description |
| Exogenous | Zoning policy at the site | The type of use foreseen for the site according to the local zoning plans, e.g. commercial area, mixed-use area, etc. |
| | Building use for the site and associated permitting | The type of usage approved for the building itself (e.g. office use, commercial use, warehouse, etc.) and any associated applications for a change of use or permitting processes |
| | Economic or business development | Existence or possible use of relevant city or private support programs (start-up or innovation promotion, personnel development, creative interim uses, etc.) |
| | Neighbourhood or community development | Existence of or possible participation in city-level or district-level strategies or social support programs |
| Endogenous | Visitor traffic | Planning for and effects of possible visitor flows to the lab on the neighbourhood, both in normal operation and during events (e.g. parking, traffic volume at certain times of day, etc.) |
| | Noise and air pollution | Experience with or recording of possible noise or air emissions from lab operations and their possible effects on the neighbourhood |
| | Relationships with neighbours | Interaction with neighbours (residents or businesses in the immediate vicinity) in the context of lab operations, in particular identification of other potential disruptive factors or conflicts that are relevant in the context of the use permit |
| Material and waste | | |
| | Factor | Description |
| Exogenous | Waste disposal | Existence of special disposal options (e.g. recycling, waste separation) at the lab site or close by |
| Endogenous | Procurement and use | Availability and possible use of material from local/regional sources |
| | Re-use | Opportunities to re-use materials, e.g. local or regional networks or suppliers |
| Networks | | |
| | Factor | Description |
| Exogenous | Production und other producers(location) | Presence of other Fab Labs/makerspaces, crafts, or further manufacturing in the neighbourhood or in close proximity to the lab |
| | Educational or research infrastructure (location) | Presence of schools, universities, universities of applied sciences or other educational institutions in the neighbourhood or in close proximity to the lab |
| | Cultural and social infrastructure (location) | Presence of social and cultural facilities, actors and initiatives in the neighbourhood or in close proximity to the lab |
| Endogenous | Production und other producers (interactions) | Interactions with other labs, makerspaces, craftspeople or similar producers in the neighbourhood or city |
| | Educational or research institutions (interactions) | Interactions with schools, educational institutions, research organizations in the neighbourhood or in the city |
| | Cultural and social institutions (interactions) | Interactions with social and cultural institutions in the neighbourhood or in the city |
| | Community outreach and lab offers | Development or adaptation of lab offers or communication about the type and scope of offers for specific target groups in the neighbourhood or city |

Table 2: Factors of urban integration.

Factors of local planning and useage, central to this research, were generally mentioned less frequently in the reviewed texts than the other categories. The descriptions of space and buildings were much more detailed, and discussions of land use or permitting concerns were found in only a few instancecs (e.g. ARMONDI/DI VITA 2021; BUTZIN/MEYER 2020). The exogenous factors of zoning and use/permitting here seem to be handled as preconditions by operators of some production sites or, in one Hamburg case, were avoided through temporary exceptions. At the city level, economic development policies that also include opportunities for support for small-scale production and produers and social support or inclusion programs have been found to be an important contributor to success (ARMONDI/DI VITA 2021; SCHROCK/WOLF-POWERS 2019). Nuisance concerns and potential conflicts with other uses in the neighborhood were not as present in the case studies as the urban planning discourse would imply. The Hamburg OpenLabs did not yet experience any conflicts or complaints from their neighbors, despite the production of noticeable fumes and noise. The lab management mentioned their attempts to limit the use of loud or odor-producing machinery to the times that they perceived as less bothersome for others. Similarly, negative impacts of visitor traffic have not been an issue for these labs so far.

Concrete discussion of material and waste was also less prevalent in the examined cases than for the built environment and networks categories. Still, endogenous aspects were revealed. The sites are described both as re-users of materials from local waste streams or within their own material-product production flows, as well as generators of waste for disposal in the larger urban waste management system (PRENDEVILLE et al. 2017, UNTERFRAUENER et al. 2017). While their production activities are both influenced by and impact local materials' use and re-use, one Hamburg case demonstrates the reliance on the overall urban waste disposal system. In this case, the lab manager collects and transports recyclable waste materials from the lab themselves, as these would otherwise not be be separated from non-recyclable waste in the city's commercial waste pick-up.

The networks category has a high level of endogeneity. Especially in exchanges with the Hamburg Open Lab cases and in the exploration of their actor networks, it became clear that some small-scale production sites seek out other networks in the city and play a major role in bringing together diverse, interdisciplinary actors from the larger community and fostering their cooperation. This does not necessarily happen organically, though, and others have found cases with more insular approaches and describe barriers to engagement and inclusivity, such as cost to users and capacity of lab manangement (VINODRAI et al. 2021).

For our network factors, we differentiate between the interaction with these networks and their location in proximity to a production site because it cannot be demonstrated so far that the presence of a small-scale, accessible production site such as a Fab Lab or makerspace acts as a driver or barrier for further production, educational, or cultural/social organisations to locate or operate within a certain area. This is rooted in our focus on the current situation at existing sites, where the presence of certain network infrastructures acts more frequently as a siting criterion or is used as a resource according to the site's goals related to, e.g., marketing, reputation-building, or increasing the user base. However, we consider this a tentative classification and see potential for the location factors in this category to be endogenous when considering implementation of accessible production sites at larger scales.

## 6 DISCUSSION AND CONCLUSION

From an urban planning perspective, these factors highlight the multi-layered nature of urban integration of spaces of production, which must go beyond purely spatial considerations, as well as the bi-directional impacts of these spaces in and on the local urban and social fabrics. With respect to the potential contribution to urban resilience in the long term, we posit that small-scale, accessible, digital production sites, such as Fab Labs or makerspaces, hold potential to address certain weaknesses of urban resilience efforts. Wardekker (2021) describes the risk of the Resilience Planning framing to fail in "dealing with social aspects" and of the Resilient Community Development framing to over-emphasize those who "can afford to think about the future."

Enagement of the public is a key defining element of this type of production. This engagement is the significant connector to the Resilient Community Development framing. The factors show that FabLabs are more than economic projects but contribute to the socio-economic development of the quarter. This also means that different actors and responsibilities come together (schools, social workers, universities etc.) with, in many cases, differing goals (education, workforce development, inclusion, etc.). The low barrier to entry and participation in production that these labs and makerspaces share can contribute to the broader community's exposure to resilience discourses and enable the uptake of more resilient practices, in accordance with the social innovation role assigned to them by current research (e.g. GARNIER/CAPDEVILA 2023) and in the Fab City context (DIEZ 2012; DIEZ 2016). In urban development and social terms, this finding implies a need for economic development and community development organisations to take small-scale, accessible, digital production sites into consideration for funding or other incentivisation in order to take advantage of their non-economic benefits. The intensive networking work done by the production sites themselves within their communities implies future potential for them to act as anchors or draws for other community development organisations and resources. The necessary scale of implementation to achieve this and the concrete socio-economic impacts for surrounding neighborhoods should be explored further.

Also with regard to integrative potential, the factors related to materials and waste highlight the role of small-scale, acessible production sites as part of a *circular* local production ecosystem, as envisioned in the Fab City concept. A production site must not necessarily explicitly express circularity goals, but many do (e.g. UNTERFRAUENER et al. 2017, PRENDEVILE et al. 2017). The two Hamburg case studies provide good examples of this. Not only are products developed using recycled materials or for re-use, both Open Labs are active in the development of circular business models that seek to increase access to circular products and material flows. Thus, they are not only users, but supporting supply of local materials and useage opportunities in the larger urban area.

This reseach highlights weaknesses of urban planning's formal structures to enable such bottom-up forms of resilience development. Within the Resilience Planning framing, Fab Labs are an example of an experimental approach that can challenge traditional system assemblies and demonstrate new decentralized arrangements. In terms of planning policy and regulation, the capacity of these spaces for fluid and changing types of production calls into question the strict functionalism of traditional zoning and usage practices in urban planning. These production sites are not pre-designed and pre-ordained production lines in a traditional industrial sense, but intentionally adaptable and multi-functional spaces. Conventional zoning and useage regulatory structures struggle to incorporate this flexibility, although flexibility is what Resilience Planning calls for.

The factors of urban integration presented here provide only an initial overview of aspects which can be considered at the intersection of small-scale production and urban planning and development concerns. In order to identify and elaborate more concretely the impacts of these factors on the implementation of labs and makerspaces in existing urban neighborhoods and the impacts of these sites on the neighborhoods themselves, further research is needed. The factors must be verified and validated through empirical studies both of existing production cases as well as of city-level strategies such as the Fab City initiative. This is planned as a next step in the Fab City project in Hamburg.

In addition, we hope to draw attention to the need for further development of planning and governance instruments that respond to the systems challenges and potentials of the integration of urban production in mixed-use areas. The issue of gentrification as it relates to urban production and manufacturing should especially be investigated in greater detail. Not only must industrial gentrification, the movement of these users out of existing neighborhoods, be better understood, but also social gentrification, or the extent to which the production sites themselves may contribute, whether intentionally or not, to the dismantling of historical neighborhood social networks and structures (see e.g. DE BOECK/RYCKEWAERT 2020; MARTIN/GRODACH 2023; SCHROCK/WOLF-POWERS 2019). These debates tie into the larger discussions of the trade-offs of the evolution and equilibrium perspectives of urban resilience which Wardekker (2021), among others, also describes. For small-scale, accessible, digital urban production to be implemented as a tool to support overall urban resilience in the long term, these risks must be made explicit and policy and practice adapted to respond to them.

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