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Principles and Design Scenarios for Sustainable Urban Food Logistics

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Food and nutrition systems are linked to all Sustainable Development Goals (SDGs), which makes their transition toward social-ecological behavior patterns crucial for an overarching sustainability transformation. The perspective of (urban) logistics is of special interest. It couples the production and consumption physically and virtually. In this context, we shed light on the design of the turnover point of food in urban areas from the supply chain toward consumers and contribute to an overarching systemic perspective toward establishing a sustainable multilevel food system. We describe current patterns in urban food systems and propose several principles for sustainable design of (urban) food systems based on concepts such as (regional) collaboration and food literacy. Using these principles, we provide four design scenarios that concretely imagine future urban food consumption and production patterns titled "slow stock supply service," "deliver into the daily walk," "central district food depot," "super food action place." With this work we provide a starting for reflecting whether certain combinations of principles actually lead to patterns of daily life that are feasible, acceptable, or desirable. Moreover, we provide an initial qualitative assessment to stimulate further research that explores scenario pathways and incorporates additional indicators regarding the impact on social-ecological. We open up various research questions with regard to the overarching question of how urban food logistics should be designed to be consistent with the SDGs.

Keywords: transition design, sustainability assessment, logistics, urban food systems, design scenario

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INTRODUCTION

Food and nutrition systems are linked to all Sustainable Development Goals (SDGs), which makes their transition toward social-ecological behavior patterns crucial for an overarching sustainability transformation (Rockström and Sukhdev, 2016; Willett et al., 2019). Food production and consumption systems are investigated from various perspectives, but so far only to a limited degree from the perspective of interconnecting logistics (Poore and Nemecek, 2018). Proposing visionary scenarios about the design of food systems and its product service systems can lead the way forward.

Existing research focuses on differentiated aspects of consumption and production as major cornerstones for a transformation of food systems. There are various contributions in the context of lifestyle changes and behavior addressing nutritional aspects, environmental footprints of diets or menues, or cooking and disposal behavior (Schmidt and Matthies, 2018; Speck et al., 2020). On the production side, examples of recent research address the transition of agricultural systems toward approaches with less negative ecological impacts, e.g., on biodiversity, as well as the sustainability management of supply chains (Rockström et al., 2017).

In this context, the perspective of (urban) logistics is of special interest. It couples the production and consumption physically and virtually. We understand logistics as a functional interconnecting system carrying nutrients from agriculture, agroforestry, or synthetic production through economy and society. Logistics interacts with attitudes, interpretations and associated action patterns that materialize in objects and service systems (Shove et al., 2012). Therefore, logistics becomes a central management tool and can support establishing resource-efficient product-service systems and lifestyles with low carbon and material footprints (Lettenmeier et al., 2014; Lettenmeier, 2019).

Here, we shed light on the design of the turnover point of food in urban areas from the supply chain toward consumers. We contribute to an overarching systemic perspective toward establishing a sustainable multilevel food system. At the turnover point, the requirements of both, production and consumption, need to be met and interact with each other. Looking at examples of within-minutes grocery delivery services such as Gorillaz, Getir, or GoPuff, steady physical accessibility to a diverse selection of food products seems to be the standard demand pattern of many consumers driven by options offered by the internet and the COVID-19 pandemic (Murphy et al., 2020). Only a highly efficient logistic system allows for this propelling demand to be met. Logistics horizontally connects the associated product-service systems and plays a key role for organizing lifestyles, households, grocery stores, and out-of-home catering as an integrated nutritional system. Currently, the turnover point of food toward consumers is mainly designed to simply meet the demand. There is huge potential to design this point of interaction differently for a sustainability transformation of food systems.

Departing from this rationale, we summarize current patterns observed in urban food systems and summarize principles that can guide the sustainable design of food systems. We exemplarily use selected principles to generate design scenarios of the logistic urban turnover point. We finally derive several research questions for the way forward.

CURRENT PATTERNS IN URBAN FOOD SYSTEMS

We describe current patterns in urban food systems along the perspectives of diets, place of ordering, and place of consumption. As a frame for discussing these patterns, we focus on negative environmental and health impacts that could be reduced by adopting more sustainable production and consumption patterns.

Diet patterns in modern urban areas of industrialized countries result in severe pressures on the environment, have strong negative health impacts and may lead to social imbalance. Thus, the proportion of nutritionally valuable product groups such as fruit, vegetables and high-fiber foods in the diet of industrialized countries is lower than recommendations by research and public bodies such as the Food and Agriculture Organization of the United Nations (FAO) suggest (Zinöcker and Lindseth, 2018; Carbone et al., 2019; Willett et al., 2019; FAO, 2020). Despite a trend toward more vegan and vegetarian diets in certain social milieus and the increasing availability of plant-based meat substitutes in supermarkets and discounters, the consumption of meat and dairy products exceeds a sustainable level regarding health and the environment (FAO, 2020; Rödl, 2021). The variety of food offers has increased and opens up new possibilities of nutrition, diets and enjoyment. In average, still, the current diet patterns are characterized by a too high calorie, fat, sat and sugar intake, in particular, because of high consumption of fast food or convenience products and sugar-sweetened foods and soft drinks (Zinöcker and Lindseth, 2018; Carbone et al., 2019; Willett et al., 2019).

So far, the existing dietary patterns are conditioned by a close interaction of dietary culture and trends, as well as the nutrition and shopping environment and exposure to food (WBAE, 2020). The classical supermarket is still the most important grocery sales channel, followed by hypermarkets and discount stores. The range of products offered in food retail and accordingly the size of supermarkets have increased steadily over the past 50 years (European Commission, 2014). The most common mode of transport for consumers to reach these purchasing locations–the so-called last mile–is by car (Stelwagen et al., 2021). Online grocery retail is still a niche but a trending segment due to an increase in door-to-door delivery services during the Covid-19 pandemic (Worthy, 2021). An overarching systemic and spatial management of food supply structures is missing. Out-of-home catering is the second largest sales channel in the food industry and apart from short-term declines during the Covid-19 pandemic, the market is growing strongly (BVE, 2021). Reasons for this include increasing mobility due to longer distances between work and home, but also the improved economic situation of households (BVE, 2021). This leads to a dissolution of classical meal structures (time and place) and the need for prepared food that is available at various locations at any time.

The expanding number of articles in supermarkets and discount stores as well as an extensive gastronomy and fast-food offering in urban areas are significantly increasing our exposure to ubiquitous food availability. Thus, the food supply is now independent of traditional seasonal and regional availability with major implications for consumer behavior and eating habits. For example, spatial differences in the distribution of such concentrated food sources show systematic associations with overweight and obesity (Cooksey-Stowers et al., 2017; Aiello et al., 2019). One reason is the exposure to, often "unhealthy," snack and take-away foods in environments where we are

TABLE 1 | Principles for sustainable food systems (incomprehensive collection).

No	Principle	Description	Exemplary reference
Production side: sustainable supply chains			
Reduce the distance of consumers to the production side, virtually and physically.			
1	Make use of resource-efficient regional and seasonal product-service systems	Local or regional production leads to shorter transportation distances and potentially more seasonal diets, still, potential rebound effects need to be considered. Several studies provide counter arguments (Paciarotti and Torregiani, 2021; Stein and Santini, 2021), that are, however, based on existing transportation patterns and production technologies, whereas we assume less resource-intensive and innovative patterns instead. In addition to its low-distance characteristics, local food also offers the potential to create identity, improve working conditions, and foster food literacy. It can also be characterized as experienceable with its appealing narrative.	Paloviita, 2010; Schmitt et al., 2017; Paciarotti and Torregiani, 2021; Stein and Santini, 2021
2	Establish solidary and transparent supply chains	Social conditions of food production as well as animal welfare are a major issue. Transparency is a major precondition toward solidarity between living beings and sustainable decision-making. A major next step can be the individual involvement in supply chains.	Beile et al., 2007; Allen, 2008; Boddenberg et al., 2017
Consumption side: diets			
Assess diets and support adoption of sustainable diets			
3	Increased consumption of plant-based products	In terms of agricultural production, plant-based products have lower environmental impacts than animal products in almost all cases. A variety of meat alternatives can support a dietary switch. A full supply of essential micronutrients such as vitamin B12 can be artificially produced using biological or chemical process engineering. If meat is perceived as indispensable, cultured meat could be an alternative.	Marlow et al., 2009; Poore and Nemecek, 2018; Willett et al., 2019
4	Prepare creative seasonal recipes	Seasonal recipes can lead to reduced environmental impacts (e.g., reduced need for greenhouses), but should be creative and, thereby, attractive for consumers and cantines. Several studies point out the importance of farming efficiency instead of seasonality (Foster et al., 2014). The proposed principle might still create market signals and boost the learning curve of regional production. Impacts from transport will then become more relevant in the future.	Macdiarmid, 2014
5	Prepare recipes fostering biological integrity	Consuming food that that preserves or fosters ecosystems and biodiversity, e.g., by polyculture-farming or farming of diverse varieties, ensures compliance of food systems with a planetary boundary at very high risk (Steffen et al., 2015). The connection between biodiversity, agriculture and private consumption can be communicated and promoted through food.	Chaudhary and Kastner, 2016; Crenna et al., 2019; Monetti et al., 2021
Consumption side: lifestyle and behavior			
Embed sustainable diets in daily routines and lifestyles			
6	Support consumers' planning and decision-making capabilities	The need for and ability to plan individual food schedules has increased with the COVID-19 pandemic. This ability needs to be enhanced for making full use of options to synchronize actual demand, shopping behavior, and preparation of meals to establish sustainable food consumption patterns and to reduce food waste.	Hagemann, 2015; Murphy et al., 2020
7	Benefit from healthy daily routines	Food consumption needs to be considered as an integrated part of healthy daily routines. Consumption offers and habits need to be developed accordingly in an integrated way. A simple example is having the possibility to pick up food by bike or foot.	Corburn, 2021
Interface consumption and production: (urban) logistics			
Optimize the last mile by cooperatively interconnecting services and actors as well as building knowledge for sustainable food consumption patterns			
8	Decentralize urban distribution for easily traversable distances	Both logisticians and consumers should be enabled to reduce the need for advanced energy services on the last mile such as motorized transport.	Tripp, 2019
9	Create a system supporting successful and schedulable deliveries	Successful deliveries avoid unnecessary transportation for redelivery. Beyond door-to-door services, success can be realized, e.g., by pick-up hubs. Further, delivery with sufficient lead time provides time for efficiently organizing logistics in contrast to spontaneous deliveries which should on be an accepted exception.	Gevaers et al., 2011; Kahlenborn et al., 2018; Tripp, 2019; Kronmueller et al., 2021
10	Pool services and reduce redundancies using digital technologies	Efficient and potentially cooperative organization of services reduces environmental impacts, e.g., by pooling instead of single deliveries or intelligent warehousing instead of area-intensive product presentation, or district/city-wide coordination of the management of leftovers or expired products.	Hagemann, 2015; Tripp, 2019; Paciarotti and Torregiani, 2021
11	Communicate impacts consumer- orientated for fostering reflexive decision-making	At the point of sale, communication of impacts needs to be simple at first glance and initiate a reflection and change of decisions, e.g., by online filters of food by health or environmental impact in a sense of negative and positive nudging.	Hagemann, 2015; Speck and Liedtke, 2016

(Continued)

TABLE 1 | Continued

No	Principle	Description	Exemplary reference
12	Interconnect with other systems to focus on physically relevant hot spots	As an example, in the context of food, sustainability is often connected to waste management and recycling with a strong focus on packaging as a discursive flashlight. However, regarding environmental impacts it is more important to discuss what we eat, not how food is packaged. Hence, packaging should, e.g., also be evaluated regarding its communication function. The focus of communication across sectors should address the key impacts.	Paciarotti and Torregiani, 2021
13	Disseminate transferable successful sustainable product-service systems internationally	Although not all innovations are transferable due regional and cultural differences, the mutual learning for sustainability between cultures through reflecting and adapting successful patterns and product-service systems can lead to significant change. This requires establishing advanced multilevel knowledge systems inspired by bottom-up solutions (Bickel et al., 2020; Bickel, 2021). Historic patterns of transatlantic consumption (McDonald, 2013) motivate to design this transfer actively instead of simply letting it happen.	McDonald, 2013

under more time pressure–such as the workplace (Burgoine and Monsivais, 2013). High amounts of food losses also characterize the food systems in the context of modern urban areas that are mostly caused at the end of the value chain at retail and consumer levels (Gustavsson, 2011). For example in Germany, the majority of food waste, more than a half, is generated in private households, resulting in food waste on consumer level of 75 kilograms per person and year compared to about 365 kg per person an year of food intake (Noleppa and Cartsburg, 2015). Inadequate planning of household purchases is an important factor. Appropriate purchasing strategies are often lacking, so that too frequent and too much is bought and the subsequent consumption is not always possible in the necessary time. This also includes a lack of knowledge about the quantity of stocks at home. Supporting factor is the food retail with too large package sizes as well as promotions, which encourage purchases without the product actually being needed (Gustavsson, 2011; Noleppa and Cartsburg, 2015).

PRINCIPLES FOR SUSTAINABLE FOOD SYSTEMS

Transforming food systems toward sustainability requires positive principles that can guide the process of establishing successful sustainable product-service-systems. In the following **Table 1**, we consolidate principles emerging from a short literature review and our own ongoing transdisciplinary research. Obviously, the table is incomprehensive and only a starting point to structure, reflect, and assess this kind of principles.

DESIGN SCENARIOS FOR FUTURE FOOD SYSTEMS

Using above principles and relying on methods of sustainable transition design (Liedtke et al., 2020, p. 164), we provide four design scenarios that concretely imagine future urban food consumption and production patterns. We picked a selection of principles as an orientation and explored potential future patterns. Using a selection only leads to blind spots, of course, but helps to explore and understand the nature of individual principles for using them in more comprehensive approaches. Here, the resulting scenarios are an attempt to translate principles into a tangible form of communication to better express their meaning and potential impact. In accordance with the basic idea of speculative design (Dunne and Raby, 2013), we interpret the principles here in an extreme form leading to rather dystopian or utopian scenarios.

In **Table 2**, we briefly describe and assess the scenarios that we named "slow stock supply service," "deliver into the daily walk," "central district food depot," "super food action place." We also provide a rough qualitative impact assessment of the potential realization of the scenarios.

Slow Stock Supply Service

Many food purchases are routine and can be calculated. This is specifically valid for food that is bought in stock, such as canned food, rice, noodles, nuts, etc. A delivery service that delivers non-perishable food to the customer's doorstep 1–2 times a month could have good sustainability potential (No. 9).

Through anticipatory delivery, producers and traders can adjust to efficient order pooling (No. 10). Consumers can opt for a convenient subscription model after making their purchase decisions. This is adjusted month by month according to demand, also possible with AI support (No. 6). With this basic delivery, the weight of remaining grocery shopping is significantly reduced. This could lower the barrier to doing the remaining trips on foot or by bike (No. 7). Suppliers could deliver flexible quantities in this system to ensure optimal package utilization (No. 10). This service leverages users' pre-existing planning expertise for efficient delivery (No. 6). A flexibility commitment can be complemented by other services. The implementation barrier for further multi-use systems is lowered, as users can return the deposit objects with the next delivery. Well suited to create long-term customer loyalty, which can increase the ability to plan. Subscriptions such as those common in solidarity farming could give producers even more planning security through a purchase guarantee. This could be

TABLE 2 | Overview and assessment of design scenarios.

Potential change on/design scenario	Slow stock supply service	Deliver into the daily walk	Central district food depot	Super food action place
Key characteristics	Online purchase and planning, delivery to home, non-perishable food only, periodical but rare delivery	Delivery to a place where you pass by anyway, frequent and short-notice delivery, mainly fresh food.	All the food for a district is stored centrally and delivered at short term to supermarkets, restaurants and canteens	This could become the local supermarket if we order our food online: Community kitchen, inspiration and learning kitchen, pick-up station, community room, bistro.
Main concretized principles informing the design scenarios	Good pre-planning, pooling, avoiding the trip to the supermarket on the greenfield	Fast food deliveries with the minimum of emissions	Small storage and presentation areas in the district, optimal interlinking and rerouting of perishable foodstuffs	Sustainable conversion of shop floor space
Positive environmental impact	**Medium**: mid-term planning allows for optimizing routes and delivery frequencies	**Medium:** less motorized deliveries to the doorstep, presentation space no longer necessary	**Medium:** Networking of all food actors in the district	**High:** efficient sharing of cooking infrastructured and effect of education on sustainable consumption patterns
Change of daily routines/behavior	**Medium:** consumers might maintain their routines, use the service for convenience, and, for convenience, still use cars for lightweight purchases	**Medium:** planning for turnover and transport of goods in daily routes	**Low:** no siginificant change on consumption side, mainly optimization of and different interactions in logistic planning	**High:** cooking and eating could become more of a semi-public routine
Rebound risk	**Medium:** if the order is in addition to the usual trips to the supermarket	**Medium:** if in additional many deliveries are carried out to the doorstep	**High:** if networking does not work well risk of duplicated infrastructure	**Medium:** if, for example, many people get a fully equipped private kitchen and a complete public kitchen.
Impact on cooling logistics	**Low:** possible with a focus on more non-refrigerated foods	**High:** in the best case, the private refrigerator is unnecessary.	**Low:** Smaller refrigeration volumes in the supermarket	**High**: Refrigerator mostly in cold chain, private refrigerators maybe less because eating at home takes less place

implemented by a full-range retailer, but it seems more effective to design a platform and pooling business: Orders are placed via an app/website, these are passed on to various grocers, and the orders received are delivered in batches.

This type of delivery would have no direct influence on chilled products. Indirectly, a shift toward non-perishable food could possibly be observed.

Deliver Into the Daily Walk

Delivery to the door is particularly resource-intensive (Stelwagen et al., 2021). With a delivery to a place where users often go anyway, this route could be made less resource-intensive. These might be, for example, cafés, gyms, kiosks, additional dispensing points or parcel machines designed for this purpose. The option to pick up food in Micro-Depots could be created here. The prerequisite for a saving is that the user's path is covered with manual power (No. 8). This would reduce unsuccessful delivery requests (No. 9) and allow for bundled deliveries to stations (No. 10). The route optimization becomes less fragmented and probably shows energy-saving potentials in comparison to driving to individual doorsteps. Deliveries with short delivery times can thus be made in a comparatively ecological manner.

The impact on the refrigeration system might be that deliveries would be divided into 4 categories: Frozen, chilled, untempered and kept warm. A refrigerator for this service would not require a (poorly insulating) glass door, as is common for commercial refrigerators. The marketing of the product has already been successful. In the case of very centrally located collection facilities, a private refrigerator could be omitted. With the proviso that the ordered food remains edible until consumption (e.g., by smaller reusable packages).

Central District Food Depot

Would it be imaginable for each district to have a central food logistics center (darkstore)? In contrast to current logistics centers, not only the own shops would be supplied, rather all actors in the district that sell food, e.g., supermarkets, snack bars, gastronomes and online suppliers use this center cooperatively (No. 10). Due to the short distance to the point of sail, retailers could reduce their own storage space and refill stocks even more quickly.

With a view to avoiding food waste, food that is about to spoil can be re-routed in the short term. An unexpectedly low demand for a vegetable in the supermarket could lead to prompt recycling with a discounted delivery for a caterer. The possibilities to utilize food that has to be used very soon might be higher for professional kitchen staff than for private consumers (No. 6).

Presumably, discounters would have to bypass such a warehouse for efficiency reasons. A virtual integration via a central food delivery reporting center could be useful for each neighborhood. This would also make it possible to determine the state of healthy nutrition in the neighborhood. Based on a good data protection concept, measures could be derived from this [e.g., increased advertising for plant based products or the addition of micronutrients (No. 3)].

For chilled food there is no direct change here. In the long run, smaller storage quantities in the supermarket could lead to fewer refrigerated shelves in the store and to a (more efficient) cold storage in the central warehouse (No. 10).

Super Food Action Place

The growing, emerging acceptance of online grocery retailing will put stationary shops under increasing pressure. This change could be shaped with new offers. A combination of food retail and gastronomy can serve to introduce consumers to creative sustainable recipes and thus function as a space for experiencing and learning about responsible, and enjoyable nutrition and contribute to the further development of food literacy (Müller and Groeneveld, 2016; Speck et al., 2021). In addition to the already mentioned pick-up services, places remaining as shops can also accommodate one or more of these services (No. 1–13):

- Rentable kitchen for cooking evenings with friends. In the long term, the private kitchen could be reduced in equipment and size.
- Manual cooking show, an event where all participants cook the same dish. It is consumed together at the location or as a personal delivery to the family.
- Bistro with daily specials as a well-balanced alternative to the snack bar. It can replace the fast food at home and can be conceptually linked to the existing salad bars in supermarkets.
- Supermarket between open-plan office, meeting place and café as urban lounge. In the best case we get a lively place for interpersonal encounters and negotiation processes and establish a public place that supports shaping a sustainable society.
- Food showroom where new food products are presented. Seasonal fruit and vegetables can be promoted with recipes. There are tasting samples of the cooking boxes for sale. The purchase is completed online. The focus is on sustainable food education.

CONCLUSION

A key aspect that we promote with our principles and sketches of tangible scenarios is that product-service systems should be based on (regional) collaboration and food literacy in order to reach sustainability targets. We are convinced that such collaboration can be economically beneficial for households, economy, and government. With this work we provide a starting for reflecting whether certain combinations of principles actually lead to patterns of daily life that are feasible, acceptable, or desirable. Moreover, we provide an initial qualitative assessment to stimulate further research that explores scenario pathways and incorporates additional indicators regarding the impact on social-ecological systems. A challenging but promising task will be to describe the kind of presented rough sketches more quantitatively considering additional characterizing dimensions and assess their economic feasibility and evaluate them within more robust theory-based impact assessment models (Coryn et al., 2011; Ibrahim et al., 2018). On this basis, combinations of principles could then be ranked regarding their impacts on sustainability and finally introduced in high-level decision-making. Our approach leads us to the following incomprehensive list of various research questions that we deem relevant for the transformation of food systems.

- What influence does the design of the logistic system have on the type of food consumed, the amount of food and packaging waste and the design of the required technical equipment and infrastructure?
- What is the effect of the point of sale shifting toward virtual places on food packaging? Would packaging be designed more user-oriented than sales-oriented?
- What are suitable, differentiated, urban communication strategies for fostering the adoption of sustainable modern consumption patterns?
- How can district-wide food planning be realized by collaboration between governance and the stakeholder of the production and the consumption side?
- Which target conflicts exist regarding the use of space in cities between the food, energy, and mobility system and what are suitable indicators for decision-making?
- How can the speeding cultural change with regard to food in the sense of the exnovation of unsustainable and adoption of sustainable food consumption patterns be modeled?
- How can the discipline of design, especially with regard to the sub-disciplines of product and communication design, contribute to making future scenarios more tangible and discussable?
- How can creative ideas from the discipline of design be translated into a quantitative form for informing the creation and evaluation of scenarios?

These detailed questions should all be seen in light of the general overarching question of how urban food logistics should be designed to be consistent with the SDGs.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

CT, MB, and LH: conceptualization and writing. MS and CL: supervision and reviewing. All authors contributed to the article and approved the submitted version.

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