

International Journal of Food Design
Volume 8 Number 1

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Received 22 June 2021; Accepted 20 December 2021

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Food markets as circular digital hubs: Prototyping enabling ICT solutions for urban food systems

ABSTRACT

The challenges posed by the environmental sustainability and circular transition of food chains increasingly see the emergence of practices that link strategies and policies to territorial pilot projects that connect physical and digital infrastructures. This aspect is particularly evident in the change of urban production–transformation–distribution–consumption models. They are the basis of a complex system that influences individual and collective behaviours, life within neighbourhoods and the intertwining of incoming and outgoing food flows as the waste flow. The article will discuss the insight emerging from REFLOW, an EU H2020-funded project. It runs from June 2019 to May 2022, aiming to build an integrated approach for developing new participatory design and co-design practices dedicated to innovative and circular urban metabolisms to promote circular solutions capable of bringing environmental, social and economic benefits. In particular, the Milan Pilot involves the municipality of Milan, local makerspaces and FabLabs, agri-food enterprises and other local stakeholders. They collectively worked on municipal food markets to upgrade them into circularity hubs. The Milan Pilot – named ‘Food Market 4.0’ – concerns the design and prototyping of

KEYWORDS

urban metabolisms
agrifood systems
covered food markets
systems design
participatory design
digital transformation
circular transition

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three product-service systems solutions to increase the circularity of the municipal covered markets and their offer service related to agri-food products. The solutions implemented are linked to a data layer that will be the basis of a city-wide renewal process of the 22 other ones. The prototypes could represent some of the building blocks of the datafication of the food distribution metabolisms and the start of a new interactive process of selling connected with other possible service offers.

URBAN CIRCULAR ECONOMY AND FOOD SYSTEMS: DESIGNING 'FROM FARM TO FORK'

With the rapid growth of urbanization processes in the last decades, cities have become enormous centres for transforming material and immaterial resource flows, hosting a complex system of agents and concentrating most of the world's wealth. This phenomenon makes the urban scale a suitable yet challenging context for undertaking Circular Economy (CE) interventions. Indeed, the collaborative dimension finds its ideal space in cities through experimentation and prototyping activities, taking advantage of conditions such as the high concentration of resources, capital and data to host and share relevant experiences within national and international networks.

Relevant contributions by academics and experts describe CE principles and possible urban scenarios of applications, indicating tools and methods for dealing with metabolisms' complexity to develop circular practices in cities. They presented the transition towards sustainable futures as a long-term and systemic intervention. The definition of three implementation levels of CE found a scientific consensus (Suárez-Eiroa et al. 2019). The micro level refers to the transition processes towards CE activated by companies through the adoption and integration of cleaner production and eco-design approaches. The meso level entails the development of eco-industrial parks and other types of production networks through the symbiotic association between industrial realities that usually do not interact with each other. Finally, the macro level refers to the transition of cities, regions and countries towards CE. At this level, adopting eco-city programmes, collaborative consumption models, innovative waste management and zero waste programmes suggested redesigning the industrial system, the infrastructure system delivering services, the cultural framework and the social system that characterize the intervention context (Ghisellini et al. 2016).

According to the widely used definition provided by the Ellen MacArthur Foundation, 'the Circular Economy is a systems solution framework that tackles global challenges like climate change, biodiversity loss, waste, and pollution' (Ellen MacArthur Foundation 2017: n.pag.). By focusing on the development of a circular vision in cities, the Ellen MacArthur Foundation has identified three principles that are able to ensure the transition of urban contexts towards CE and to be adopted as a basis to define the interpretative categories for implementing pilot projects:

- design out waste and pollution to preserve human health and natural systems from negative externalities of economic activity;
- keep products, components and materials in use and at their highest value, favouring inner loops of resources through the adoption of design approaches that encourage reuse, remanufacturing and recycling;
- regenerate natural systems by fostering flows of nutrients in and around cities.

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Therefore, the principles of CE are integrated and adapted to the city context to generate an urban system that can improve citizens' resilience and living conditions while reducing pollution, creating local value loops and minimizing waste generation. To achieve these goals, 'innovation in Circular Economy requires a systemic approach where cities must act as key facilitators by stimulating co-creation, co-design and co-implementation with different actors and citizens at both the local and the international level' (Santonen et al. 2017: 3). The involvement of all social actors requires the development of capacity-building and sharing knowledge activities that foster awareness about CE and the possibilities for sustainable change that it can offer, encouraging all stakeholders to play an active role within the transition process. Furthermore, the effective participation of the whole society also makes the establishment of innovative and democratic governance models indispensable to ensure that the benefits deriving from the implementation of a circular vision address interests of all actors, including the most vulnerable (Friant et al. 2019).

The rise of the urban CE is stimulating the circular transition of agri-food systems. FAO launched twenty years ago (2001) the multidisciplinary initiative Food for the Cities. It promotes the creation of more green and resilient food systems that combine urbanization, ruralization, social and environmental sustainability. The concept of City Region Food Systems (CRFS) introduced a systemic approach to the management of flows and metabolism (people, goods and services) related to food production, processing, marketing and consumption, considering urban centres and their peri-urban and rural surroundings.

Over the past decade, the development of (political, productive, scientific and technological) collaborative networks, platforms and initiatives working on food cities has strengthened. The set of transition initiatives is part of a series of visions on the transition that range from the powerful transformative frameworks of research policy such as the UN Sustainable Development Goals (SDGs) and the innovation policy missions that substantiate the EU Green Deal based on the concept of mission-oriented innovation (Mazzuccato 2018). The 'Farm to Fork Strategy', which is totally in tune with the Green Deal, is based on a fundamental principle – food, the environment, health and agriculture are closely linked, and food systems must become sustainable. From 2021, FP9–Horizon Europe, with its pillar on food, bioeconomy natural resources, agriculture and environment, has earmarked millions of euros to fund research and innovation projects to meet the challenges of the Farm to Fork Strategy.

These frameworks have also fostered the development of specific experiences, capabilities and pilots, as in the case of the C40 cities (<https://c40.org>) and the Ellen MacArthur Foundation networks (Ellen MacArthur Foundation 2019), up to some cases with a particular programme and actions such as those of the Milan Food Policy (<https://foodpolicymilano.org>). Policy, research and citizen engagement initiatives deriving from or linked to these frameworks introduce some (circular) innovation challenges, starting from a general assumption – to promote a systemic change on urban food systems, the involvement and systemic participation of all actors, their processes and their methods of relations are needed. The European Commission's study titled 'Food in Cities' (De Cunto et al. 2017) highlights the main reasons why cities want to develop urban food strategies: food security and nutrition, the livelihood of urban and peri-urban

food producers, job creation and economic development, protection and restoration of the local ecosystems.

The main challenges cities face in developing food strategies are integrating data and information on food systems, including digital technologies, and creating and scaling up existing solutions. The *Food in the Cities* report also identifies innovative elements to focus on for the development of local initiatives related to food strategies (De Cunto et al. 2017: 29): emphasis on community buy-in (bottom-up approach), enhancing participation in design and implementation of food-related actions (co-creation approach), local empowerment with social inclusion, shortening the food supply chain, adopting systemic thinking related to food chains, translocalism as an approach to networking, knowledge exchange and cooperation. In summary, urban food strategies promote a coordinated set of actions that work on the sustainability transitions of food systems. These actions require a systemic design approach that can align the digital technology landscape for the urban CE with the resources of urban foodscapes (Sonnino 2016).

Digital technologies for (urban) CE: A preliminary overview

The Ellen McArthur Foundation emphasizes that, in addition to the shared production of durable goods, one of the most important directions of CE development concerns the evolution of product-service systems from the digital perspective. Digitalization is one of the main enabling factors to increase visibility and smartness in products and goods, knowledge on their location, conditions and availability throughout their life cycle (Ellen McArthur Foundation 2015, 2016). The New Circular Economy Action Plan (European Commission 2020) mentions, among its cross-cutting actions, the theme of transition to the CE through research, innovation and digital transformation. The Horizon Europe programme will support the development of indicators and data and new solutions for circularity considering the role of digital tools to achieve circular objectives. In particular, the Action Plan states that

[d]igital technologies can track the journeys of products, components and materials and make the resulting data securely accessible. The European data space for smart circular applications will provide the architecture and governance system to drive applications and services such as product passports, resource mapping and consumer information.

(European Commission 2020: 21)

This statement reinforces the idea that digital technologies combined with ICT and, more recently, machine learning foster the development of participatory processes based on data, which produce results relevant to the CE (Ellen MacArthur Foundation 2016). These data can measure circularity and create innovation initiatives based on distributed technologies for the CE.

However, what is the state-of-the-art connection between digital transformation and the CE? The first fundamental reflection is that CE systems are based on and/or generate large amounts of data on production and product lifecycles, use, reuse, recycling of materials, logistics systems and actors involved in the value chain. At present, many of these data are not yet digital or are not yet digitally connected. Digitalization, therefore, offers new means and tools to access this data to arrange and coordinate information and material flows.

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The most significant contributions collected in this article propose a literature review on the state of the art of the so-called digital circular economy. Taken together, they identify the main areas of opportunity, criticalities and conceptual tools for digitization. At the same time, they also highlight a substantial and general lack of applied case studies and best practices that try to meet the digital circular economy challenges and test concrete solutions (Antikainen et al. 2018; Pagoropoulos et al. 2017; Tseng et al. 2018). The report *Digitalisation: Unlocking the Potential of the Circular Economy* highlights how the relationship between digitalization and CE is still at an early stage (EIT Climate-KIC 2018). According to the report, by unlocking the potential of the CE,

[d]igitalisation offers us the opportunity to reinvent our relationship to natural resources. IoT applications will intensify the connectivity between units, gathering data across things and people. Blockchain brings greater transparency, security and traceability. AI allows us to analyse data with greater detail and accuracy, increases resource efficiency and productivity, enables predictive maintenance, and opens up further untapped potentials.

(EIT Climate-KIC 2018: 37)

In considering digital technology as an enabling factor, the report identifies some relevant issues: the integration between software (SW) and hardware (HW), the need for complete and accurate data, an existing data access and data standard problem and the challenge of interoperability between technologies. In the context of digitalization for the CE, the main research question certainly concerns the definition of a technological landscape, that is, the set of existing digital technologies that can support the circular transition.

The report *Cities in the Circular Economy: The Role of Digital Technology* (Sukhdev et al. 2016), developed by the Ellen McArthur Foundation with Google, identifies several digital technologies that play a role as enablers of the CE in cities. On the one hand, these are technologies to obtain information on conditions, availability and flows of products, components or materials (e.g. asset tagging and geospatial technologies). On the other hand, these technologies manage open and big data on human behaviours, connected to flows' identification and tracking, allowing easy access and widespread connection between people and information on flows (e.g. data management and connectivity technologies). In official research reports on digital transformation for the CE (issued by European public bodies, private institutions and global consulting firms), various digital technology landscapes are represented, offering an overview of the families of technologies related to different CE processes. An overlap between the enabling technologies for the CE and those of the Industry 4.0 paradigm is recognizable. These representations go as far as to outline a general model of digital circular innovation based on the evident coexistence of different technology families. One of these representations, elaborated by Deloitte (Figure 1), reports a fascinating subdivision of digital technologies concerning CE transition activities: (1) technologies that support the mapping of resources or the alignment between data and material flows, (2) technologies that support the redefinition of operational models through connectivity among data, devices and stakeholders, (3) technologies that support the production or upgrade of solutions and (4) technologies that allow communication, dissemination and learning of circular practices.



Figure 1: Representation of digital technology landscape for urban circular economy. Source: REFLOW project. Credits: Politecnico di Milano, 2020.

The literature review on the development of digital innovation for the CE (Antikainen et al. 2018; Bressanelli et al. 2018) indicates that the main challenge focuses on the relationship between business models and data. These reports refer to data ownership, integration and sharing and information management and the collaborative processes necessary for their creation and acquisition. They address critical issues related to privacy, trust, intellectual property rights and require a radical change of organizational, technological and cultural mindset to organize systemic processes. Ritzén and Sandström (2017) identify technical barriers related to product design and the integration of digital technologies into production processes. From all these works, it is possible to locate, extrapolate and

synthesize some key themes or issues for the design of digital circular economy initiatives:

- *Digitalization and speed in the development, adoption and processes of CE.* The market increasingly requires using digital solutions to enable and scale up CE models. While consumers and citizens are beginning to understand and embrace the CE principles, the adaptation to more evolved and complex forms of consumption takes longer. On the other hand, many companies developing digital solutions for CE are essentially start-ups. Start-ups need to focus on business scalability and technological solutions. Both are very demanding challenges that require the involvement of human capital and the use of economic resources.
- *Digitalization and the issue of data/information quality on circular systems.* While there is no doubt that digitalization has significantly increased the quantity and volume of information exchange, the scientific literature shows a gap in the quality, accuracy of data and information and access costs. According to several reports, this is one of the main obstacles to CE development. Another relevant issue concerns integrating data between the various stakeholders within a circular system, which is fundamental to reconstructing and aligning information flows with material flows. Again, the scientific literature shows that this aspect has not yet been considered and explored with due attention (Pagoropoulos et al. 2017; Wilts and Berg 2017).
- *Digitalization and co-creation for CE.* Several scholars' analysis of the scientific literature highlights a direct and recurrent connection between digitalization and co-creation. Co-creation processes that privilege the sharing and combination of competencies from different sectors and organizations of varying nature and size (large and small, public and private, educational and productive) are considered relevant, as well as the development of project actions and initiatives that combine social participation, multidisciplinary and technological experimentation (e.g. workshops, hackathons, challenges and competitions).
- *Digitalization, distribution and strengthening of agency and individual participation in circular systems.* Digitalization supports the transition to a circular economy, stimulating the scalability and replicability of the business models and distributing agency between consumers, local businesses and citizen communities.
- *Digitalization allows the reallocation of knowledge, structure and data ownership through novel technologies like distributed ledgers.* Still, it provides for the development of more connected and long-lasting relationships between the various stakeholders of the system, including users. Digitalization can develop new business models based on advanced forms of end-user participation in monitoring and controlling resources and material flows (Salminen et al. 2017).

In this context, makerspaces and FabLabs should also have a role in offering spaces for co-designing innovative tools and testing prototypes while encouraging local production, repair and digital manufacturing (Ellen MacArthur Foundation 2017). Indeed, the definition and implementation of open data platforms and digital applications are essential to enhance the development of interactive and collaborative processes in addition to monitoring and reporting activities (Santonen et al. 2017). Moreover, digital technologies can also

support the identification of challenges related to material flows in cities, orienting decision-making processes towards the development of circular solutions (Ellen MacArthur Foundation 2017). Local governments can play a crucial role in engaging national and business actors, providing new financial instruments and supporting education and training to increase general awareness and social participation within the circular transition path (Ellen MacArthur Foundation 2015, 2017).

FORECASTING THE CIRCULAR TRANSITION AND DIGITAL TRANSFORMATION OF THE MUNICIPAL MARKETS

The main drivers of digital transformation for the CE can be used to explore the implications for urban and peri-urban agri-food systems. Covered food markets are historically symbolic places where food distribution and transformation take place in cities. For this reason, it is significant to study the role and evolution of these places from an urban CE perspective. The hypothesis is that municipal food markets may be relevant to stimulating the urban CE. Their digitization is an opportunity to promote the circular transition of urban and peri-urban food systems.

Market halls, indoor markets, covered food markets, municipal markets and food halls are all terms to define indoor spaces or buildings (or part of it) in which a sale of food together with other products by independent producers or retailers occurs. The market hall is an indoor market widespread in many European countries. Most of these places follow either the nineteenth-century models of the French Napoleonic and British Victorian central markets ('the great age of market halls', Guardia et al. 2018: 102; Dobraszczyk 2012) or the earlier twentieth-century polycentric or distributed model of the neighbourhood food markets (see Figures 2 and 3).



Figure 2: Livorno central market. Credits: Massimo Bianchini, 2020.

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Figure 3: The Prealpi Market, one of the neighbourhood markets that are part of the renewal strategy promoted by the municipality of Milan. Credits: Politecnico di Milano, 2020.

Municipal markets are one of the most historical and iconic places within urban foodscapes (Morgan and Sonnino 2010). Due to the fast-growing urbanization, municipal markets were invented to improve the supply of food and its preservation (Schmiechen and Carls 1999), to monitor the economic flows linked to the buying and selling of food and increase controls on food safety, to facilitate public access and to tune in to the population's eating habits. Particularly, municipal markets have been recognized and celebrated by governments and industry as valuable social spaces that can address growing public health issues in urban areas (Machell and Caraher 2016).

Traditionally, food halls and market halls sell meat, fish, poultry, milk and dairy products, bakery products and fruit and vegetables and are sensitive nodes for urban food metabolism. Modern market halls can also exist in a gourmet food hall because they can sell food and tell the story of its origin and production processes. Over the decades, municipal markets have experienced a phase of rising and development followed by a long period of stagnation and partial decline. This last process is favoured by the residential decentralization and suburban expansion, the development of supermarkets and shopping malls with their food courts and, ultimately, the extreme diversification, servitization and digitalization of the food offered in urban contexts (Jones et al. 2007). Especially in the last twenty years, we are witnessing a divergent development of municipal markets in many cities. On the one hand, a structural and economic decline can be observed in many markets. On the other hand, these places are the subject of revitalization strategies as both 'bastions of authenticity' and 'multicultural places' in urban areas undergoing globalization and gentrification.

Furthermore, municipal markets have been considered part of a revitalization strategy that gives them a more significant role than hubs of cultural

identity and sociality. The idea is that they can be service hubs concerning the development of a culture of circularity rather than the simple application of new healthy and food lifestyles (fight against obesity). The contemporary strategy of revitalizing municipal food markets as healthy hubs or proximity food hubs seems still more a plan or promise for innovation and food tourism than a fact for many. At the same time, it is not realistic to assume that covered food markets can return to their original function and role in society as the sole provider of healthy food and diet to the urban poor (Schmeichen and Carls 1999). As proof of this, in a general context of a lack of scientific literature dedicated to the circular transition and digital transformation of municipal markets, there is a body of publications interested in markets from the point of view of their historical, cultural and architectural evolution about the demographic, social, economic, tourist and cultural development of cities.

The analysis of existing literature combined with the identification of best practices allows us to identify some significant aspects to reflect on the digital transformation and circular transition of the markets covered:

- *Municipal markets between centrality and proximity, and hybridization of their distributional formats.* The introduction and development of polycentric municipal markets have combined (in some cases replaced) the concept of proximity with centrality. Municipal markets, especially polycentric ones, have tended to become functional poles within neighbourhoods due to their ability to aggregate activities and services complementary to the food supply around them (Fava et al. 2016). Finally, municipal markets implement public-private partnerships to develop a spatial integration between urban public service's historical meanings and the distributional format's hybridization (Tamini 2015).
- *Municipal markets between the defence of authenticity and hyper-localism and the reinvention of traditions and multiculturalism.* Municipal markets are sensitive places in the relationship between the global and local food production and consumption dimensions. In today's markets, various food cultures coexist in different percentages and configurations: food that corresponds to local traditions and tastes, multi-ethnic and immigrant-run food stores that respond to the tastes and dietary needs of more recently settled communities and more experimental food that looks to cosmopolitan globalism, ranging from local food experiences to gastronomic tourism (Crespi-Vallbona and Dimitrowski 2007; Berbel-Pineda et al. 2019). Markets, therefore, have to manage a diversified food supply in terms of type and quality, which corresponds to the complexity of the management of food chains.
- *Municipal markets between local community-building, inclusiveness and social participation.* Municipal markets are by definition places centred on human interaction and sociability. Historically, markets played a significant role in gender inclusiveness by aggregating female communities (vendors, stallholders and customers). Markets were essentially an extension of daily life in the local community and the basis for building neighbourly relations and local social networks (Fava et al. 2015). Nowadays, many market halls facilitate the relationships between citizens, regional economics, and cultural promoters, and sometimes they are considered as specific community centres, especially when they are placed close to other services of public interest such as health centres, libraries, schools or in urban areas

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often exposed to processes of economic and urban regeneration (Tamini 2015).

Several examples of transformation and reinterpretation of municipal (central and polycentric) markets are connected to the redevelopment or revitalization of neighbourhoods.

Among the most relevant and recent examples is the Östermalm Saluhall in Stockholm, whose renovation has been completed in 2020, making the new food hall the centre of an urban food district and one of the nodes of the city's artistic and cultural system. The Markthal in Rotterdam (Figure 4) is a newly conceived municipal market (opened in 2014) that has become one of the city's attractions. In addition to its futuristic architecture, the market has combined the desire both to develop a market for the sale of organic and multi-ethnic food with the housing needs of an apartment block enclosing the market and to create a contemporary hub with renewable events and installations. Other new markets, such as Market Hall in Ghent in Belgium and the fish market in Bergen, are based on projects that aim to build new forms of urban and social interaction with the historic centre of the two cities.

A particularly relevant case is the strategy of renewal and innovation of the system of the 40 municipal markets of Barcelona, launched in 1992, which



Figure 4: The Markthal in Rotterdam. Credits: Paul Arps, <https://www.flickr.com/photos/slapers/15564386409>. Accessed 22 February 2023.



Figure 5: Mercado de Santa Caterina in Barcelona. Credits: William Veerbeek, https://www.flickr.com/photos/william_veerbeek/40486492955/in/photostream. Accessed 22 February 2023.

constitutes an accurate model of intervention (Adjuntament de Barcelona 2015). By the end of the 1980s, the municipal markets had become decadent and obsolete places from a structural and commercial point of view. The strategy worked to renovate the markets with customized interventions, integrating them into their neighbourhoods and giving them a role as social regenerators. For example, the redevelopment of the Santa Caterina market (Figure 5) included a social housing initiative based on constructing an apartment complex for senior citizens near the market. In particular, the Barcelona strategy aims to make markets more sustainable by introducing pro-energy efficiency measures and a new model for waste treatment and creating a food culture that favours a healthy city and promotes local commerce and local producers. Many markets already offer home delivery services and have collection points, and some are linked to cooperatives and associations that favour the employment of people with disabilities. In addition, there is a communication strategy that aims to connect suppliers and sellers and network markets.

Municipal market renewal literature and case studies show that these places are predisposed to circularity at 360°. However, best practices show that markets are in the early circular transition and digital transformation stages. To date, the digital layer of municipal markets mainly concerns services such as reservations and delivery or consultation of the market's food offer. In parallel, the issue of sustainability, quality and food safety is related to the certified origin of the products sold (farm-to-table products and Protected Designation of Origin products) rather than the development of digital systems for the traceability of goods. However, environmentally sustainable markets are still

considered islands of circularity digitally disconnected from urban metabolisms. Similarly, municipal markets live with another ambiguity: they are places characterized by a personal social and relational dimension not yet intermediated by the digital. Essentially, they are still analogue places that (r)exist within digitally dense urban contexts.

1. *Polifactory*, the makerspace-FabLab of Politecnico di Milano (<https://polifactory.polimi.it>), *OpenDot* (<https://opendotlab.it>) and *WeMake* (<https://wemake.cc/>).

DESIGNING AND DIGITIZING THE NEXT MUNICIPAL MARKET: MILAN AND THE PILOT PROJECT FOOD MARKET 4.0

Municipal markets are beginning to connect with new services and networks, from food apps to food delivery. This broader product–service innovation horizon comprises technological, social, service and design-driven innovation. REFLOW (<https://reflowproject.eu>, 2019–22) is a Horizon 2020 Innovation project that aims to develop circular and regenerative cities through enabling active citizen involvement and systemic change to rethink the current approach to material flows in cities. The project utilizes FabLabs and makerspaces as catalysts for change in urban and peri-urban environments and develops an open data platform and dashboard with instruments, data visualization tools and reinforced by blockchain technology accessible to citizens, specialists and policy and industry leaders to support and guide the transition towards achieving circular cities.

Within REFLOW, six pilot cities across Europe (Milan, Vejle, Paris, Berlin, Amsterdam, Cluj-Napoca) are testing approaches to city circularity, each focusing on a different resource flow. The municipality of Milan, with three makerspaces,¹ is developing the pilot project Food Market 4.0 that aims to support the city's vision on circular food by providing sustainable solutions at the local market level. The pilot project fosters and tests sustainable food logistics, develops market labs to disseminate circular practices, tracks agri-food products' origin and quality and analyses the interrelations between rural and urban communities. The Milan Pilot engages and maps municipal markets' circular and digital needs as well as establishes co-design labs to co-develop circular solutions, prototyping and experimenting with these solutions.

The final objective of the Milan Pilot is to impact food and market policies and make current practices of the 23 local city markets more circular. (The whole system of municipal markets includes also 90 outdoor neighbourhood markets, with about 8000 people employed [Milano Food Policy 2018].) The municipality of Milan, in close connection with EXPO 2015, has implemented several actions in the field of food policy focused on strengthening the link with the peri-urban agricultural area, promoting the recovery of food, promoting innovative agricultural initiatives, implementing a civic crowdfunding platform for food issues, creating synergies between the various actors in the food system and implementing a long-term vision on food choices to fight poverty, promote sustainable diets and support the fight against waste by promoting reuse and recycling.

The municipality of Milan implements two main relevant actions related to the municipal markets. The first action concerns the strategy for the renewal of city markets (changing their management model), having as a best practice the redevelopment of the historic Lorenteggio Market, which has become a place for social, cultural and food promotion. The second action is the renewal of SO.GE.M.I. general food market (<https://sogemispai.it>; Figure 6) and its implementation of food hub, having the Rombon Market as a pilot project of circularity on a vast urban scale. SO.GE.M.I. is a company that, on behalf of the



Figure 6: SO.GE.M.I. food hub in Milan. Credits: Politecnico di Milano, 2021.

2. The ethnographic study involved a process of field observations and subsequent interactions (through focus groups, questionnaires, interviews and shadowing) with SO.GE.M.I. general market operators and representatives of some of the 23 covered markets (Morsenchio, Prealpi, Ticinese and Ferrara). The whole process, organized by the three FabLabs involved in REFLOW (Polifactory, OpenDot, WeMake) and the municipality of Milan, took place in several phases between spring 2020 and autumn 2021.

municipality of Milan, manages all the city's wholesale food markets (fruit and vegetables, fish, flowers and meat), guaranteeing their operation by providing qualified services to support the commercial activities of the operators.

The Food Market 4.0 pilot project considers the municipal markets a strategic public asset to work within a broader administration policy of 'hybridisation of these places'. The pilot project uses the municipality of Milan's food policy and circularity strategy as a policy framework. At the same time, the innovation framework is the strategy for the new digital manufacturing (ManifatturaMilano) that focuses on the involvement of start-ups, FabLabs, universities and research centres to support new circular business models with a high social impact.

The Food Market 4.0 pilot project works on SO.GE.M.I. and existing municipal markets as a testbed for circular solutions to be prototyped in the REFLOW time horizon and applicable or scalable on other markets. Within REFLOW, municipal markets are considered actors that stimulate the transition towards circular business models based on sustainable processes of access, consumption and fruition of products and services linked to the agri-food system. Municipal markets are also considered a distributed system of 'hyperlocal' logistics platforms that integrate and support the development of services on an urban scale.

An ethnographic study² of SO.GE.M.I. general food hub and covered food markets has brought to light a series of criticalities and opportunities fundamental for constructing some circularity scenarios within the project pilot on which to co-design and prototype product-service solutions. There is

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‘shrewd’ management of waste and refuse in municipal markets. The quantities of waste and refuse produced by the markets are minimal compared to the whole urban agri-food sector. Individual stallholders are generally very careful and organized, more for economic than environmental reasons. The level of digitization of municipal markets is deficient; the markets tend to be analogue. For example, in many markets, Wi-Fi connectivity is absent. At the same time, most individual operators lack adequate technical and digital skills to develop more complex and interactive forms of circularity. An overall reality of disconnection between markets and neighbourhoods emerges in the markets analysed, both from a social and a service point of view. In particular, except for a few markets (e.g. Lorenteggio), there is a general difficulty in building stable relationships with citizens that can translate into projects, initiatives or solutions with/for the neighbourhood. Similarly, market operators have an excellent knowledge of the products they sell, but have problems in developing direct relations with small agri-food chains because other parties intermediate them.

The vast majority of the operators of the covered markets get their supplies from the SO.GE.M.I. general market, but at the moment, neither the tracking of data on the origin of the products nor the weighing of fruit and vegetables at the market entrance takes place.

Finally, within the SO.GE.M.I. general market, 1.5 million kilograms of fruit and vegetables are collected every year by voluntary associations to be donated to citizens in need. But even the donation processes are not characterized by traceability and circularity.

The essential elements that emerged from this work define three Food Market 4.0 scenarios: (1) working more on prevention than on waste management, (2) working on the creation of HW/SW solutions to define the first level of digitalization of markets through the use of digital prototyping technologies (creation of digital twins of the warehouses of various operators), (3) encouraging interaction and integration between markets and district agri-food chains for whole ‘Farm to Fork’ traceability.

Finally, three scenarios are defined: ‘Food Market 4.0 Dashboard’, ‘Foody Zero Waste’ and ‘Milano Prima Seconda’.³ In particular, the ‘Food Market 4.0 Dashboard’ is related to the co-design and prototyping of an HW/SW infrastructure for tracking, managing, data analysis and servitization of food flows in the Milan covered markets. It relates to SO.GE.M.I. general market and the Morsenchio Municipal Market (<https://consorziohorsenchio.it>) opened in 1960. The project related to this scenario aims at transforming the municipal market as a neighbourhood (logistic) hub and as a junction of different flows through the prototyping of a smart system for tracking and storage of goods to facilitate the supply and sale of agri-food products (internal and external smart tracking and storage system). Thanks to this smart system, it will be possible to create connections with other sustainable systems for the management of orders and delivery of agri-food products (inbound and outbound intelligent delivery system), and with infrastructures for spaces inside and outside the market equipped to attract and promote the local movement of goods and people or the development of new services (smart mobility and smart picking).

The development of municipal markets as urban logistics and service hubs is not only conceivable but also possible thanks to the rapid evolution of products–services for integrated logistics (from smart boxes for the transport of

3. ‘Foody Zero Waste’ concerns a series of digital solutions that encourage donation, facilitate management and increase the distribution of unsold food within the SO.GE.M.I. general market. It relates to the work of RECUP (associazionerecup.org/i-mercati), a voluntary association that annually recovers about 54 tonnes of fruit and vegetables within the general market (equivalent to 21 tonnes of avoided CO₂ emissions). ‘Milano Prima Seconda’ concerns a distributed system of mapping, collection and exchange of secondary raw materials for new and higher-value products. It is connected with the work of Ibrida (<https://ibridabirra.com/it/home>), a Milanese circular craft brewery that produces beer starting from unsold bread.

4. See the following exemplary cases: Delò and Serving Box (<https://servingbox.it>), Foodlogica (<https://foodlogica.it>), Farmstead (<https://farmsteadapp.com>), Nuro (<https://nuro.ai>) and Tradelens (<https://tradelens.com>).
5. The first prototyping phase was completed in November 2021, and the testing phase within the Morsenchio Municipal Market was completed in March 2022. See full description of Food Market 4.0 here: <https://reflowproject.eu/blog/food-market-4-0-dashboard/>. Accessed 14 March 2023.

fruit and vegetables to intelligent storage systems and sustainable last-mile logistics), a rapid expansion of IoT solutions and (semi-)automated systems for smart delivery and, finally, the use of blockchain for the traceability of agri-food chains.⁴ These solutions are undergoing a process of technological democratization that can easily connect to existing systems, are compatible with open HW/SW systems, can be redesigned in a simplified form using open design and open HW and then materialized through the support of digital fabrication technologies.

The Food Market 4.0 Dashboard tracks, controls and functionalizes the connections between the supply chain, management and logistical planning of food streams in and out of the markets. It also facilitates matching the demand and supply of goods to implement new B2B and B2C procurement models. The Food Market 4.0 Dashboard has been prototyped⁵ and tested at Morsenchio Covered Market (Figure 7) developing the following elements:

1. *Handling*. Handling goods through an efficient HW system that avoids damage to the products.
2. *Check-in*. Recognition and tracking of incoming and outgoing products through digitized checkpoints and tags applied to an 'intelligent' box model.
3. *Display*. Display of goods through versatile structures for different stall configurations.
4. *Virtual organization*. Management of displayed and stored goods through an interactive dashboard.
5. *Picking and delivery*. Integration of last-mile activities via mobile application and smart locker.



Figure 7: Prototype being tested in the shop of the Morsenchio Municipal Market.

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CONCLUSIONS

The Food Market 4.0 Dashboard thus introduces a pragmatic product–service solution that stimulates the circularity of municipal market processes and develops an innovative concept of experiential circular action. It aims to encourage an urban-scale multistakeholder vision concerning the markets' digital implementation necessary to enable the relationships and the possible future connections with neighbourhoods and the urban food systems. It is a new experience generation that stimulates the engagement of different categories of users, citizens and stakeholders and is grafted onto this technological infrastructure. These implemented technologies and a new service offering create new emerging roles – like the emergent one of the augmented stall manager-entrepreneur – and renovated strategies for developing a post-smart city vision of what urban digitalization is.

It also means that this might be a starting point to build a new kind of engagement that will progressively include the municipality itself and the citizens' communities in a positive understanding of what a circular distribution and consumption facility might be.

The experiment will open new research and development perspectives that will originate new public policy visions and entrepreneurial perspectives transforming an existing and traditional infrastructure in a powerful network of connected circular places.

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SUGGESTED CITATION

Bianchini, Massimo and Maffei, Stefano (2023), 'Food markets as circular digital hubs: Prototyping enabling ICT solutions for urban food systems', *International Journal of Food Design*, Special Issue: 'Designing Digital Technologies for Sustainable Transformations of Food Systems', 8:1, pp. 89–108, https://doi.org/10.1386/ijfd_00052_1

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