Chapter 18
A Prosumer Approach for Feeding the Digital Twin. Testing the MUST Application in the Old Harbour Waterfront of Genoa

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Abstract Supporting the settlement systems' life cycle management through synchronisation of the real world with a virtual platform constitutes the horizon for the MUST team research (Maintenance Urban Sharing Tools) with the Departments of Architecture (DiARC) and Structures for engineering and architecture (DiSt) of the University of Naples, Stress Scarl and ETT SpA. Living digital simulation models are based on information analysis and constant data supply. The research identifies the involvement of the settlement systems users through creating collaborative information flows, one of the driving factors of the digital revolution. The paper introduces the connotative aspects of the MUST application (Smau Innovation Award 2019, Campania Start-Up 2020 funded project) to identify the building and urban system loss of functionality. With the support of an experiment conducted in the waterfront area of the old harbour of Genoa, the paper identifies strengths and weaknesses in using the MUST application to support and streamline the Digital Twin that ETT S.p.A. is implementing with the DSH2030 (Digital Sustainable Harbor 2030) project. A prosumer perspective is the foundation of this research focusing on the sense of responsibility of communities towards the built environment and on the willingness of individuals to invest in care actions. The paper returns the research results achieved to date with an open and public model design, equipped with different interfaces to meet the diverse needs of the groups involved, allowing expert citizens to interact and report in progress feedback.

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18.1 Introduction

The Internet of Things (IoT) and cloud computing renew systems and process in several production sectors, from manufacturing to aerospace, impacting design, production and maintenance (Tao et al. 2019). In the building sector, the digital transition, although an essential choice for urban governance, is prolonged due to the built systems complexities, stakeholders' diversity and construction technologies' evolution. However, scholars admit that digitalisation applied to maintenance and management could significantly improve built environments' qualities and companies' business.

The contribution resumes the studies that started with the development of MUST, Maintenance Urban Sharing Tool (already registered at SIAE with progress number D000014807), a digital application designed to involve citizens in buildings' life cycle extension.

Potentialities and gaps of Digital Twins (DTs) applications for urban maintenance are the entry point of this paper. It outlines the feasibility of synchronisation scenarios between the real world and a virtual model, extending the data acquisition process to dynamic and conscious sensors.

DTs support managers and technicians in decision-making approaches on digital clones of physical assets by simulating adaptive scenarios in response to incoming data from real-time operations.

Developed as integrated multi-physics, multi-scale, probabilistic simulations, DTs use the best available physical models and sensors to mirror the life of their real twins (Glaessgen and Stargel 2012).

In a scenario marked by collaborative approaches to the built environment management (The Council of Europe Secretariat in Consultation with the Faro Convention Network (FCN) Members 2018), extending the data acquisition process to citizens' involvement in faults detection is the research hypothesis discussed for a proof-of-concept DT under development in the old harbour waterfront Genoa. The achieved results can be traced back to the definition of renewal coordinates in urban maintenance and DT's functionality extension with data output from MUST.

18.2 Digital Transition for Urban Maintenance

Identifying the built environment as a complex system is an underlying hypothesis for the first studies on maintenance methods and procedures at an urban scale (Ciribini 1986). Since the 90s, with the first British Standards, the scientific community worked for the involvement of administrators, companies and users within a technical, cultural and social process able to manage the stratified and interconnected layers connoting the built environment. Over thirty years, maintenance emerged as an iterative strategy based on archived data, forecasts and inspections aimed at conserving and realigning the performances provided by a building asset within acceptable values, contrasting failure and obsolescence processes (UNI 11257 2007).

An expansion of perspectives, witnessed today by the UNI 13306: 2010 and 10147: 2013 standards (UNI EN 13306 2010; UNI 10147 2013), is recorded with maintenance defined as a complex activity carried out by organisations capable of integrating structured information, technical know-how, strategic and managerial skills and to guarantee, over time, a quality condition (Hauashdh et al. 2022).

The concept of *service* informs the approach implemented in the last decade (Ferreira et al. 2021), helping to trace the cultural coordinates of several experiences in the field, united by the commitment to (1) raise the maintenance procedure to a planned activity, legitimately and definitively included in the project; (2) define the design, executive and inspection techniques to minimise costs; (3) bring communities back into the care and custody process.

The concept of DT introduced by Grieves (2002), with the Conceptual Ideal for Product Lifecycle Management (PLM) as the digital representation of a physical asset and the automatic connections that bind them together (Grieves and Vickers 2017), opens up new scenarios for maintenance planning in the construction sectors. DT is "An integrated multi-physics, multi-scale, probabilistic simulation of a vehicle or system that uses the best available physical models, sensor updates, fleet history and so forth, to mirror the life of its flying twin" (Glaessgen and Stargel 2012).

Despite several projects carried out in the construction sector to develop DTs during the design and execution phases, problems still emerge when the smart city scenario refers to the already built environment (Bujari et al. 2021). Main difficulties can be attributed to: (a) complexity of elements constituting the physical space that should be reported in the virtual product; (b) quality and quantity of data sources that feed the model; (c) communication flows between them. Only a few experiences (Wray 2020) demonstrate the effective convergence between urban maintenance and DTs, showing the improvements that DTs could bring to the maintenance plan (Deng et al. 2021).

DTs are expected to support policymakers and professional practitioners at the urban scale, controlling spaces' and elements' behaviours compared to users' needs and foreseeing performance maintenance through the life cycle (Zheng et al. 2020). According to McKinsey (2015), DTs in urban care processes will provide up to USD 630 billion in potential savings in the construction market in 2025. In this perspective, DTs should have a predictive attitude to evaluate real systems' current and subsequent states and predict failures McKinsey (Tjønn 2019). Furthermore, this prediction improves when the DTs include more information about the physical features, the ongoing process or the operation's characteristics (Errandonea et al. 2020).

Sensors and devices for real-time data acquisition are fundamental for feeding the DTs. Their development has been fostered by the awareness of the economic benefits; these technologies can bring to the building process. An indispensable prerequisite is progress monitoring, which provides wide-ranging information on faults, relating each failure to a system of triggering causes (Olivotti et al. 2019).

Research on DTs in the urban maintenance field collides with technological difficulties in acquiring and transferring data from the real system to the virtual model. The most significant problems are related to various sources' interaction in the information process, such as asset data, operational data, historical maintenance activities and information on constructive transformations, which are decisive for assets' users and managers. Recursive data directly acquired or synthetically generated through simulation are fundamental for DTs that include information on how the performance provided improves after maintenance activities.

18.3 Methods and Materials

The paper resumes and develops further the results already achieved within the project metrics (2013–2017) managed by the Regional High Technology District for Sustainable Buildings, Stress.

The methodology is based on a mixed deductive and inductive approach that integrates the literature review results with a critical analysis of the impacts on urban maintenance reachable through adopting a DT fed by data from the MUST application.

Initially conceived for reporting faults that affect the buildings' functionality, MUST has been developed by an interdisciplinary research team, with the collaboration between architects experts in building maintenance (DiARC), structural engineers (DiSt), computer scientists (ETT) and researchers from the Regional District Stress.

Smau Innovation Award in 2019, as an Italian Excellence Model of Innovation for Companies and Public Administrations, MUST was awarded by the Regione Campania Start-Up 2020. Since 2021, this grant supports the transfer to market process. Within this funding, the Working Group prefigures an open and public model, equipped with different interfaces to meet the diverse needs of the groups involved, allowing citizens to interact and report progress feedback.

The MUST application supports the maintenance process by two main service modules: a mobile application and a web GIS-based dashboard. The mobile application is developed for iOS and android smartphones (available on the marketplaces). Once the user is registered, he can take a snap of the area; the picture is AI processed to provide the user with the best matching label to tag the identified issue. Then, the user can add further notes and submit the notification. The mobile app interoperates with cloud infrastructure (Google Firebase). A web application provides the facility manager with an intuitive dashboard to list, prioritise and supervise the maintenance interventions workflow (Fig. 18.1).

The web dashboard includes a synoptical geo-referred view of the notifications and the possibility to elaborate reports and analytics (space, time, type of issue, etc.). With the support of MUST, the research explores incremental innovation scenarios

Fig. 18.1 From the mobile app to the facility manager dashboard workflow. Authors elaboration

in the urban maintenance sector, referring the potentialities and gaps analysis to the applied research project Digital and Sustainable Harbor 2030 (DSH 2030—https://www.digitalsustainableharbour.it/), funded by the POR FESR LIGURIA.

18.4 Results and Discussion

The literature review referred to urban maintenance and DTs development returns a framework of studies in constant evolution (Bibri and Krogstie 2021). Focusing on the transition processes towards smart cities and the impacts of enabling technologies, the results can be traced back to the following three research areas:

1. methodological approaches for systematising the urban environment and studying the behaviour of units and components. Built environment care and preservation for long have been activities:
    - very demanding on a theoretical level because they are based on technical skills and analytical skills;
    - not very evident on the executive level because they do not require sophisticated technical skills;
    - not significant on the media level, not very attractive and exciting.
2. failure processes analysis with the support of dynamic and conscious sensors to presume the life span of sub-systems and technical elements. In the urban maintenance segment, predicting and mitigating failure processes affecting the maintenance sets emerge in an international arena as an issue that concerns

buildings users, real estate managers, condominium administrators, technicians and the whole community. Hence, adopting sensors capable of monitoring the state conditions of urban systems is a central issue of many studies (UNI EN 13306 2010; UNI 10147 2013).

3. inspection activities with preventive effectiveness. The literature review provides a framework of studies to reorganise the management coordination for urban services. Reactivating the symbiosis between built assets and communities (The Council of Europe Secretariat in Consultation with the Faro Convention Network (FCN) Members 2018) becomes a horizontal challenge for quality preservation and transmission. An expanded awareness about the need to share responsibilities towards built assets through values matured in contexts and handed down over time profoundly emerges from the analysis of documents produced by international organisations and scholars. A call to engagement and empowerment renews the action of expert knowledge and communities.

According to point 1, urban spatial areas can be assumed as the reference context where the interaction between DT and MUST could successfully work. Within each spatial area, the object of observation is the aggregated maintenance set, identified for an organisational and economic optimisation of the maintenance practice (UNI 11257 2007). The aggregation aims to synthesise and optimise the framework of knowledge, compare the characterisation of the technical elements and the planned activities, relate them to the worksite of the urban space and seek in the latter unexpressed potential and constraints.

According to point 2, a prosumer perspective, crasis of the terms producer and consumer is at the basis of the idea of feeding the DSH 2030 DT with data acquired by users via mobile phones, adopting the MUST application to power the communication between real space and the virtual model.

The adoption of a data flow coming from MUST is subjected to the functioning of the DT, which must be able:

- to integrate various types of data of physical objects;
- to exist in the entire life cycle of physical objects, co-evolving with them;
- to optimise physical objects.

Three groups of stakeholders participate in the interaction between DT and MUST:

- citizens; they are the active component of the maintenance process, which initiates the reporting of faults;
- managers; they access the reports sent by citizens and urge inspections in the event of an alert;
- technicians; they intervene following the warnings with inspections and repairs.

A gradual knowledge strategy is supposed to support citizens in recognising the failure processes of sub-systems and technical components. The occurrence of events capable of affecting the real system identity is anticipated by signals that return in the virtual model, with indications offered by users about the process's extent and consequences. In addition, a database of the states according to which the failure event

Fig. 18.2 A prosumer approach for feeding the DT for urban maintenance. Data flow schematic drawing by ETT. Authors elaboration

can evolve supports the user's involvement in recognising significant conditions to prevent the onset of situations that will lead to the "cessation of the ability of an entity to perform the required function" (UNI 10147 2013).

According to point 3, the predictive and decision-making processes are reconfigured due to the synchronising between real space and virtual models with aware sensors.

The critical analysis of the impacts that a DT fed with data from the MUST application can exert on urban maintenance (Fig. 18.2) outlines:

- a framework of pervasive changes due to digitalisation on companies, markets and business models for urban maintenance. They can help:

  a. increasing the quality of the settlement system;
  b. facilitating the relationship between stakeholders;
  c. reducing times and costs, simplifying methods, promoting the predictive maintenance approach.

- future requirements regarding accuracy, functionality and integrability. They should be respected within the Digital and Sustainable Harbor 2030 (DSH 2030) project. For example, to guarantee that DSH 2030 could be able to predict the urban system response, within each spatial area, to an unexpected event before it occurs, DT should:

  a. be the most realistic representation of a physical asset, incorporating models and available information;
  b. contain all process information and acquire operational, organisational and technical knowledge;

c. always be synchronised with the physical asset;
d. be able to run simulations of physical asset behaviour;
e. be self-evaluative: it is something alive that changes, improves and evolves while maintaining the comparison between physical and virtual space.

Positive organisational consequences of the integration between DT and MUST can be traced back to the DT attitudes to:

- solve accessibility problems; hosted in the cloud, it can be accessed from anywhere and thus can provide information on the status of data;
- forecast of the evolution of failures, simulation of the effects of maintenance action;
- help the operator to perform the specific maintenance task;
- calculate the cost of the maintenance activity.

18.5 Conclusions

Assuming the built environment as a complex, dynamic and adaptive system, the research prefigures an incremental innovation scenario, with digitisation renewing the management services for the maintenance sets through synergies between stakeholders.

A theoretical framework has been traced in the international context considering organisations, municipalities and scholars' commitment to urban maintenance. DTs have been defined as models of physical assets in operation that could be applied to design a more effective preventive maintenance strategy.

Focusing on proof-of-concept DT under development in the ancient port of Genoa, the research hypothesis is to integrate the data flow with a set of information provided by citizens adopting the application MUST. Accuracy, functionality and integrability have been outlined as the requirements for a DT to support managers and technicians with remote control, predictive decision-making approaches and adaptive scenarios.

Extending the life cycle of buildings is a MUST for the community, to which research responds with the expanded sharing of monitoring, updating and programming processes.

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