PRIN: Progetti di Ricerca di Rilevante Interesse Nazionale. OUTFIT – crOwdsoUrced daTa Feeding noise maps in dIgital Twins

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Il progetto OUTFIT, finanziato dal bando PRIN 2022 prevedono la realizzazione prototipale di una mappa acustica dinamica del rumore stradale in un digital twin (DT). Il DT integrerà i dati crowdsourced alla base della mappa dinamica con i risultati dei livelli di rumore e ulteriori elaborazioni, consentendo una visione aumentata della situazione corrente e potenzialmente di relative misure di mitigazione favorendo la visione dei decisori politici e la consapevolezza dei cittadini.
Parole chiave: rumore stradale, mappa dinamica, dati crowd source, gemelli digitali

PRIN: Research Projects of Relevant National Interest. OUTFIT – crOwdsoUrced daTa Feeding noise maps in dIgital Twins
The OUTFIT project, funded by national PRIN 2022 aims at realizing a prototypal dynamic noise map of road traffic noise within Digital twin (DT). DT will include crowd source input data with output noise levels, allowing an enhanced view of actual noise levels and issues and potentially the effects of noise mitigation measures. This will boost the comprehension of current issues by policy makers and citizens.
Keywords: road traffic noise, dynamic map, crowd sourced data, digital twins

1 | Introduction

Il progetto OUTFIT è un progetto congiunto finanziato dall'Unione Europea tramite il bando PRIN 2022 in cui sono coinvolti l'istituto IPCF del CNR, il Dipartimento di Informatica dell'Università di Pisa ed il Dipartimento di Ingegneria dell'Innovazione dell'Università del Salento. Il progetto ha come obiettivo la rappresentazione dinamica del rumore stradale in un modello 3D Digital Twin attraverso l'ottimizzazione del flusso di dati relativo al rumore.

2 | Background

La stima del rumore del traffico stradale è normata sia a livello italiano che Europeo e la END fornisce i modelli di calcolo per le mappature, tuttavia negli anni è emersa la necessità di andare oltre gli indicatori medi con i quali solitamente si stabiliscono i piani di azione. La ricerca è andata verso la mappatura dinamica per poter intercettare bisogni dei cittadini non visibili con indicatori di lungo periodo e si è mostrato necessario fornire ai decisori politici un metodo di visualizzazione dei problemi e delle soluzioni che sia facilmente intuitivo e comprensibile.

Il Digital Twin urbano è uno strumento utilizzato per assistere i decisori nelle scelte riguardanti la pianificazione urbana, gli interventi di potenziamento della sostenibilità e l'ottimizzazione delle infrastrutture.

I dati utilizzati per sviluppare un rendering dinamico del rumore del traffico sono stati i dati crowd, cioè dati provenienti da fonti collettive, in particolare sono stati utilizzati i dati sui tempi di percorrenza forniti da Google Maps.

3 | Obiettivi

Gli obiettivi del progetto sono:

- Realizzazione di un database del traffico stradale ottenuto da dati crowdsourcing da utilizzare come input per lo sviluppo di un modello che stimi RTN.
- Ottimizzazione dei flussi di dati per permettere l'elaborazione dinamica dei dati del traffico e il rende-ring del rumore.
- L'output finale del progetto è un modello riproducibile tramite il quale sviluppare un Digital Twin in 3D con rendering dinamico del rumore e un sistema API per consentire l'interoperabilità degli open data del sistema OUTFIT.

4 | Elaborazione del flusso di dati

Sono stati selezionati 97 archi stradali nel centro di Pisa ed è stato sviluppato un codice in linguaggio Python in grado di effettuare una richiesta di dati (chiamata API) temporizzata al servizio di Google API Direction per ottenere i tempi di percorrenza su ogni arco ed aggiornarlo ogni 10 minuti.

A partire da questi tempi di percorrenza abbiamo derivato le velocità ed i flussi equivalenti di auto/furgoni/moto. Servendoci del modello CNOSSOS-EU abbiamo elaborato una griglia di rumore che ci permette di calcolare il livello di rumore assorbito da ogni punto sulla base dei flussi dinamici acquisiti, applicando una matrice di attenuazione del rumore in dipendenza delle caratteristiche spaziali dell'area circostante alla sorgente di rumore calcolata a priori.

La stima del calcolo al ricevitore (vedi Fig. 1) è costituita dalla somma energetica di due contributi distinti, la stima della potenza sonora degli archi che viene ottenuta dinamicamente e la stima della propagazione che viene ottenuta tramite matrice di abbattimento generata in software commerciale.

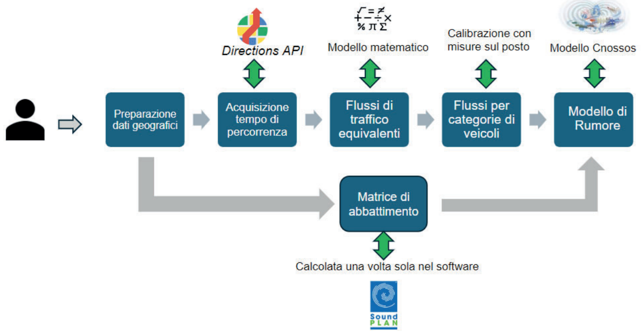

Fig. 1 – Flusso di dati dalla chiamata API ai livelli sonori
Data flow from API call to sound levels

Il risultato intermedio, prima dello sviluppo del Digital Twin, è quello di una mappa dinamica dei punti di ricezione del rumo-re stradale posti in facciata agli edifici nell'area urbana di Pisa. L'intensità del rumore assorbito da ogni punto è vi-sualizzata attraverso una scala cromatica (vedi Fig. 2).

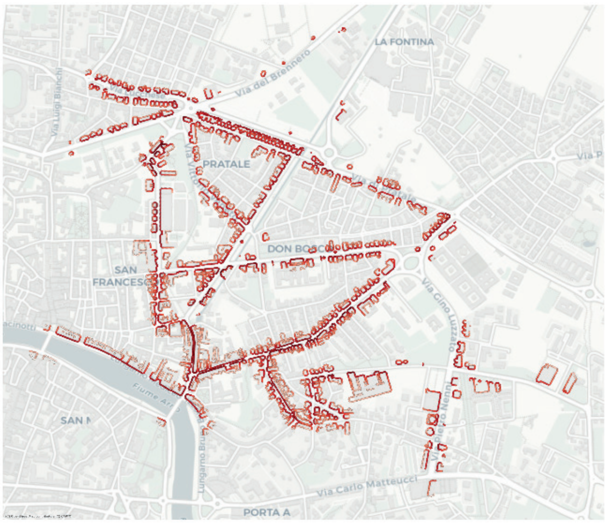

Fig. 2 – Esempio di istante temporale della mappa dei ricevitori
Example of a time instant of the receiver map

5 | Conclusioni e prospettive

Nell'area di Pisa sarà effettuata una misurazione dei flussi di traffico reali tramite l'installazione di dispositivi contatraf-fico e sensori basati su telecamere, necessari per calibrare il modello sviluppato finora ed avere un riscontro tra i livelli di rumore stimati partendo dai dati Google e quelli reali. La valida-zione del modello di traffico sviluppato nell'area di Pisa verrà poi effettuata nell'area urbana di Brindisi, dove l'Univer-sità del Salento ha progettato il Digital Twin.

Nell'ambito del Digital Twin potranno essere visualizzati:

- i dati di traffico acquisiti dal data stream;
- dati dei livelli di rumore stradale richiesti dalla normativa;
- le segnalazioni dei cittadini inerenti il rumore pro-venien-ti dai dati raccolti tramite social media e web data;
- elaborazioni di indicatori di salute legati all'inquinamen-to acustico nelle zone maggiormente esposte al rumore stradale.

Il progetto vuole definire potenzialità e limiti dell'approc-cio crowd ed è attualmente in una fase iniziale di sviluppo da parte dei partner coinvolti.

Fig. 3 – Logo di Programma e partners coinvolti
Program Logo. and partners involved

Acoustic performances of Test Cases developed within iclimabuilt project: an open innovation test bed for building envelope materials

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iclimabuilt project aims to form a cross-domain business ecosystem to support small and medium enterprises in scaling-up innovative sustainable building products and cope with the continuous rise of technological complexity by providing a single-entry point for necessary infrastructures and tools to test, validate and upscale new technological solutions. The consortium combines the capabilities of different experts, building the connection between technology suppliers and final users, based on the cooperation within interdisciplinary entities to support new product development/upscaling and testing, satisfy customer needs based on a case-by-case assessment of the underlying barriers of each technology, and eventually incorporate the next round of innovations in building envelope materials and technical systems into living labs.
Keywords: decarbonisation, sustainable building envelope technologies, testing, building performance simulations, validation in living labs

Prestazioni acustiche di componenti edilizi sviluppati nel progetto iclimabuilt, un laboratorio per l'innovazione per materiali dell'involucro edilizio
Il progetto iclimabuilt mira a formare un ecosistema aziendale interdisciplinare per supportare le piccole e medie imprese nello sviluppo di prodotti edilizi sostenibili innovativi e far fronte al continuo aumento della complessità tecnologica fornendo un punto di accesso unico per le infrastrutture e gli strumenti necessari per testare, convalidare e potenziare nuove soluzioni tecnologiche. Il consorzio unisce le capacità di diversi esperti, creando la connessione tra fornitori di tecnologia e utenti finali, sulla base della cooperazione all'interno di entità interdisciplinari per supportare lo sviluppo e il test di nuovi prodotti, soddisfare le esigenze dei clienti sulla base di una valutazione caso per caso delle barriere sottostanti di ciascuna tecnologia e infine incorporare il prossimo ciclo di innovazioni nei materiali dell'involucro edilizio e nei sistemi tecnici nei laboratori viventi.
Parole chiave: decarbonizzazione, tecnologie di involucro edilizio sostenibile, test, simulazioni delle prestazioni degli edifici, convalida in living labs

1 | Introduction

Buildings account for approximately 40% of total energy use and 36% of CO_2 emissions in Europe. According to the Recast Directive on the Energy Performance of Buildings (EPBD), all new buildings after 2020 should meet nearly zero-energy standards. This means they must have very low energy needs, primarily met by renewable energy sources. The EU's 2030 targets include at least a 40% reduction in greenhouse gas emissions (compared to 1990 levels), a 32% share of renewable energy, and a 32.5% improvement in energy efficiency, aiming to reduce greenhouse gas emissions by 80% by 2050.

From 2010 to 2016, energy consumption in buildings increased from 33 PWh to 34.5 PWh, driven by the growing floor area, which outpaced reductions in energy intensity. Therefore, there is an urgent need for a deep market transformation by deploying efficient materials and technologies in the construction sector. This is essential to support the implementation of nearly zero-energy/emission and plus-energy buildings while maintaining high indoor environmental quality across Europe. Since energy consumption in buildings is highly influenced by climate and local weather conditions, additional factors, such as environmental, technical, user experience, and design aspects, must be considered when selecting materials and technical components to successfully implement nearly zero-energy buildings (nZEBs). Furthermore, this selection of materials and design must adopt a circular economy approach, considering environmental, economic, and social impacts across value chains. A transition from a linear to a circular economy, focusing on reuse, repair, and recycling, is vital for better utilization of resources and products. In this challenging and complex context, SMEs (Small and Medium Enterprises) in the construction sector, are facing different challenges in developing, upscaling and introducing into the market new building products and solutions that could help in the decarbonisation objectives. They would need to cope with (i) the rising of technological complexity and related characterisation and testing of the performance required by the materials and systems developed; (ii) the ten-fold increase in investment needed to pass from a lower to higher Technological Readiness Level, especially passing from a small scale prototype (TRL 4) to a full-scale prototype demonstrated in relevant environment (TRL 6-7) [1]; (iii) the challenges posed by the digitalization, rising energy prices, and competition from non-European, low-labour-cost countries, which require additional investment and innovation strategies. To address these needs, the European H2020 iclimabuilt project aims to realize an Open Innovation Test Bed as an ecosystem to foster upscale innovative building envelope solutions within the building industry, by providing a single-entry-point for multi-services for SMEs, focused on:

- materials development (for improved performance of building envelope solutions);
- design and assembly of technical systems (customizable, flexible, modular and de-mountable designs);
- Virtual Performance testing (multi-physics and multi-scale building performance simulations);
- Sustainability and Health and Safety Assessment of materials and building envelope systems;
- monitoring and characterization strategies and services to support decision-making (fully monitored living labs and non-residential nZEBs);
- refined and expedited access to financing solutions to reinforce the competitiveness and extroversion of SMEs.

iclimabuilt goes beyond material-level advancements, supporting the energy transition of Europe's building stock. The project aims to take a holistic approach, viewing buildings as systems and maximizing energy-saving opportunities while using smart and energy-harvesting systems to meet the remaining energy demand as much as possible. Through this systematic approach and services, iclimabuilt aims to contribute to the cost-effective transformation of existing building stock into nearly zero-energy buildings. Among the tools and methodologies developed within the project, virtual retrofitting has been applied through Building Information Modeling (BIM) solutions, enabling the modelling of buildings and performing multiple analyses. This allows for energy performance predictions and comparisons of design alternatives, leading to better decision-making. Multiphysics simulations have been used to analyze building envelopes and predict material properties. Additionally, iclimabuilt has developed and verified robust monitoring approaches, tools, and methodologies for long-term, in-field monitoring. This helps demonstrate and validate the performance of different building envelope technologies in full-scale living laboratories.

These methods support product development for optimal building integration of smart materials and building envelope components, involving both iclimabuilt partners (as an internal validation of the eco-system) and external SMEs through an open call that was closed on Jan 24, with eight projects financed (as an external validation of the services of the eco-system).

2 | Test Cases – Acoustic performance

Within the project Politecnico di Torino was responsible for coordinating the laboratory testing of all the developed materials and building systems, to conduct thermal, solar and acoustic characterization at laboratory level, using simulation, and also in living lab scale, within their living lab. This section will focus on the description of the acoustic characterization activities.

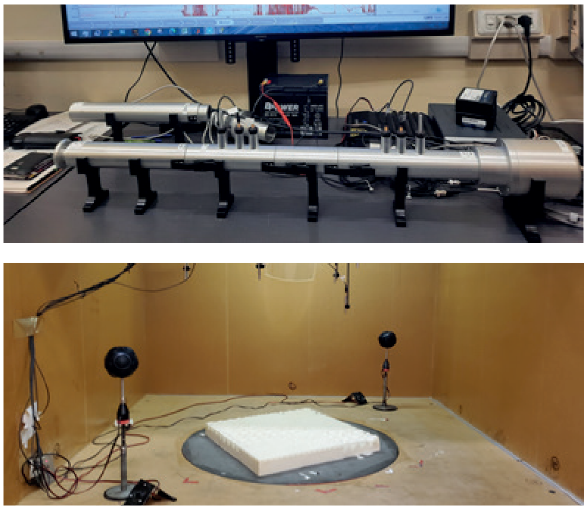

Fig. 1 – Acoustic characterization: transmission loss in impedance tube (a) absorption in scaled reverberant chamber (b)
Caratterizzazione acustica: fonoisolamento con tubo ad impedenza e assorbimento in camera riverberante in scala

Fig. 2 – Laboratory and in situ test of sound reduction index R
Misure in laboratorio e in situ del potere fonoisolante R

The designated partners developing the Pilot Lines, in collaboration with research centers and universities within the Consortium, have completely characterised raw materials. The characterizations have encompassed transmission loss, absorption, and scattering coefficients, employing various characterization techniques. The acoustic performance and characterization of the different building components developed within the iclimabuilt project (specifically building panels and components of Multifunctional Composite Sandwiches, eco-friendly concrete-based and insulation materials, as well as the performance of 3D-printed components) have been assessed through laboratory testing for sound absorption and scattering in a scaled reverberation room at the Politecnico di Torino (POLITO) laboratoriescommon acoustic materials only offer limited options for customizable geometrical features, performance, and aesthetics. This paper focuses on the sound absorption performance of highly customizable 3D-printed Hybrid Acoustic Materials (HAMs. Additionally, sound insulation has been tested using impedance tubes at POLITO [2]common acoustic materials only offer limited options for customizable geometrical features, performance, and aesthetics. This paper focuses on the sound absorption performance of highly customizable 3D-printed Hybrid Acoustic Materials (HAMs and standard ISO 10140 procedures at the HTWK (Leipzig) lab, on a innovative heat harvesting ventilated window component.

Given the inherent challenges of in situ acoustic measurements (including scale and flanking effects) and the costs associated with laboratory tests, standard methods have been compared with more suitable methodologies for in-situ testing, such as sound intensity measurements or continuous monitoring. To validate these procedures, comparative testing has been conducted on specific test cases between two Living Labs [3] (Turin and Trondheim) and the HTWK lab, where the same test case has been evaluated using the sound intensity method and the standard ISO 10140 method.

Multiphysics simulations have also been conducted to create virtual prototypes for quantifying the acoustic performance of integrated building envelope components (such as wall blocks, sandwich panels, and window frames) under various facade integration and boundary conditions. This work has utilized general-purpose multiphysics software, such as COMSOL, alongside specific acoustic modeling tools like INSUL. These have been analysed following an integrated approach into building performance simulation (BPS) software at a larger scale using Grasshopper and Revit, with the Rhino Inside plug-in.

3 | Pilot Lines

Within the iclimabuilt project, different Pilot Lines are developed using the services of the ecosystem:

- Phase Change Materials (PCMs);
- Thermoelectric Generators (TEGs);
- Multifunctional Composite Sandwiches (MCS);
- Solar-active Envelope (SAE) materials and structures for Building Integrated Photovoltaics and Solar thermal systems;
- Customizable 3D-printed components for well-being;
- Advanced cement-based materials for wall facades;
- Insulation components from wastes;
- Aerogels (AGs);
- Omniphobic coatings.

All the selected technologies have reached innovation maturity and are among the most promising advanced materials with proven technical feasibility to provide viable efficient energy-efficient solutions for the buildings of tomorrow. They are fully characterized and integrated into building envelope components within the project.

4 | Living Labs

Validated material technologies and technical systems have been integrated into advanced climate-adaptive façades and used as demonstration cases to evaluate these new solutions in a controlled experimental environment. Pilot buildings, located at real residential and non-residential construction sites, have been identified across five climate zones in Europe to serve as evaluation sites for the developed solutions to test their effectiveness in close-to-reality use cases and involving final users (Living Labs). These sites are:

- Amposta, Spain;
- Manresa, Spain;
- Turin, Italy;
- Dresden, Germany;
- Trondheim, Norway.

Each building site is a hub for material and component combinations tailored to specific climate and performance objectives. Energy performance assessments of the developed systems at both component and building scales have been conducted, considering energy efficiency improvements, thermal comfort, daylight, air quality and acoustic comfort improvements. Real-world impacts and feedback from residents on the demonstrated technologies have also been considered.

5 | Project partners

The project is coordinated by Costas Charitidis (National Technical University of Athens, Greece) and the partners (Fig. 3), from 14 EU countries, are 16 RTOs (Research and Technology Organisations), with 7 Universities, and 11 SMEs (Small and Medium-sized Enterprises), presented at https://iclimabuilt.eu/partners/

Fig. 3 – Partners map

Mappa dei partner

6 | Acknowledgements

The Authors would like to thank the partners of the project developing building materials and components, which were characterised from an acoustic point of view within the project, such as HTWK, INEGI, TUHH, BGTech, BioG3D and Rubitherm.

Bibliography

[1] J. Hensen, R. Loonen, M. Archontiki, M. Kanellis, Using building simulation for moving innovations across the "Valley of Death," REHVA Journal 52 (2015) 58-62.

[2] V. Tsiokou, L. Shtrepi, E. Badino, A. Astolfi, A. Karatza, Exploratory Acoustic Investigation of Customizable 3D-Printed Hybrid Acoustic Materials (HAMs) through Interlaboratory Impedance Tube Measurements, Acoustics 5 (2023) 653-675. https://doi.org/10.3390/acoustics5030040.

[3] L. Shtrepi, A. Gerbotto, F. Favoino, A. Astolfi, Sound insulation characterisation of innovative natural ventilated façade in the context of living lab installations, Inter Noise 270 (2024) 10094-10102. https://doi.org/10.3397/IN_2024_4388.