Change toolkit for digital building permit

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Contents

1. Executive Summary

The CHEK project (Change Toolkit for Digital Building Permit) addresses the pressing need to digitalise building permitting in Europe. Today, permitting remains largely paper- or document-based, creating inefficiencies, delays, and a lack of transparency. CHEK developed and tested a comprehensive toolkit of methodologies, tools, and workflows designed to enable automated, transparent, and standardised digital permitting. The toolkit was demonstrated in four municipalities, Ascoli Piceno, Lisbon, Vila Nova de Gaia, and Prague, across two scenarios: new constructions and renovations.

This deliverable, D6.5, Best Practices and Scalability Guidelines, brings together the findings from WP6 pilot demonstrations (D6.2–D6.4), stakeholder engagement, CHEK development experiences and exploitation insights. It identifies best practices that proved essential for successful adoption, evaluates the replicability and scalability of CHEK solutions, and provides guidelines and recommendations for municipalities, national governments, and European institutions.

The pilots confirmed eight key best practices. Establishing a baseline through process mapping and reengineering allowed cities to identify bottlenecks, redesign workflows, and introduce automation, potentially saving up to 80% of review time in Ascoli Piceno pilot. Collaborative change management, supported by the CHEK Virtual Assistant, ensured leadership commitment and cross-departmental engagement, particularly in Vila Nova de Gaia. Clear, machine-readable regulations were shown to be a prerequisite for automation, as demonstrated in Lisbon where the building height rule was successfully digitised and validated. Early steps in workflow automation, such as solar access checks in Gaia, proved that starting with high-impact rules can immediately reduce review time and encourage pre-checking by designers. Communication and transparency were enhanced through 3D viewers like VC Map, which allowed citizens and applicants to better understand compliance outcomes. At the same time, CHEK emphasised interoperability-first data handling, using IFC and CityGML profiles, georeferencing, and converters to ensure consistency across BIM and GIS systems. The modular software architecture, based on an OpenAPI approach, supported incremental adoption and integration with national platforms, while active user involvement and iterative testing ensured that tools were adapted to real municipal workflows.

Openness and compliance with international standards (IFC, CityGML, IDS, OpenAPI) were highlighted as CHEK's strongest assets, while training and user experience emerged as areas needing refinement. Documentation and tutorials already exist, but they must be consolidated and tailored more closely to municipal roles.

The scalability guidelines outline a stepwise pathway: municipalities should begin with organisational readiness through maturity assessment, leadership commitment, and training. Technical implementation should proceed incrementally, starting with the encoding of simple rules, the establishment of BIM/GIS workflows, and the piloting of targeted cases. Adaptation strategies vary depending on municipal size and maturity, with smaller towns encouraged to adopt hosted solutions and simplified training, while larger cities should focus on integrating CHEK modules into national platforms and expanding to advanced rule sets.

Looking ahead, the recommendations call on national DBP programs to adopt CHEK methodologies as reference models for process redesign, on standards bodies to formalise CHEK specifications within international frameworks, and on European networks such as EUnet4DBP to foster cross-municipality exchange and reduce fragmentation. For all levels, the next step is to bridge prototype to production by expanding rule coverage, consolidating workflows, embedding collaboration features, ensuring multilingual support, and investing in capacity building.

2. Introduction

The CHEK project (Change Toolkit for Digital Building Permit) responds to the growing demand for more efficient, transparent, and interoperable building permitting processes in Europe. Building permits are essential for regulating urban development, yet in most European municipalities the process remains paper-based or document-driven, often fragmented across departments and subject to lengthy approval times. This situation hampers innovation, increases costs for both public authorities and private applicants, and slows progress towards European policy priorities such as the Renovation Wave, the European Green Deal, and the Digital Europe agenda.

CHEK developed a toolkit of methodologies, standards, and technical modules designed to digitalise the building permit process (DBP). The project is built on prior initiatives in Building Information Modelling (BIM) and Geographic Information Systems (GIS), extending them with rule interpretation methods, automated checkers, data converters, and process mapping approaches. Importantly, CHEK placed emphasis on open standards (IFC, CityGML, IDS, OpenAPI) and modular architecture, ensuring that the solutions are interoperable and can be integrated into national and municipal permitting systems.

Work Package 6 (WP6) focused on piloting and demonstration of CHEK solutions in four municipalities: Ascoli Piceno (Italy), Lisbon (Portugal), Vila Nova de Gaia (Portugal), and Prague (Czech Republic). Two pilot scenarios were tested:

- Scenario 1: new building construction.
- Scenario 2: renovation projects.

The demonstrations, supported by process mapping, maturity assessments, and technical integration, provided a real-world validation of CHEK's methodologies and tools. Besides representing the final test of the developed tools, the final demonstrations integrated and confirmed the lessons learnt throughout the project development, both from the project activities themselves and considering the wider landscape of digital building permit with which CHEK could confront and discuss during dissemination and synergizing activities.

This deliverable, D6.5 – Best Practices and Scalability Guidelines, synthesises the CHEK outcomes to:

- Identify best practices that underpin successful digital permitting, based on lessons from pilots and stakeholder engagement.
- Assess the replicability and scalability of the CHEK toolkit, considering technical readiness, openness, documentation, user experience, language, and standards compliance.
- Translate findings into scalability guidelines, providing stepwise adoption pathways for municipalities at different maturity levels.
- Provide recommendations for future uptake, aimed at municipalities, national governments, European institutions, and standardisation bodies.

The document is structured as follows: Chapter 3 presents the best practices emerging from pilots; Chapter 4 analyses replicability and scalability factors; Chapter 5 summarises feedback from stakeholders; Chapter 6 outlines scalability guidelines; Chapter 7 provides recommendations for broader adoption; and Chapter 8 concludes with key findings and outlook.

By combining methodological lessons, technical results, and stakeholder perspectives, this deliverable ensures that CHEK's outputs are not limited to pilots but can act as a European reference model for the digital transformation of building permitting.

3. Best practices and recommendations

The CHEK pilots demonstrated that implementing a digital building permit (DBP) process is not only a technical task but also an organisational, regulatory, and cultural transformation. Across four pilot municipalities and two scenarios (new construction and renovation), a set of best practices emerged, supported by the tools, methodologies, and specifications developed within the project.

Building on these experiences, CHEK defined a set of domain-specific best practices that address technological, regulatory, organizational, and policy aspects of DBPs, beyond technical standards. These practices ensure that outcomes are not only technically sound but also scalable, replicable, and relevant to the everyday needs of municipalities and regulatory authorities.

The development of domain best practices followed the same cycle as technical best practices:

- Interim testing in pilots and workshops with CHEK municipalities.
- Structured feedback loops with international communities (EUnet4DBP, EuroSDR, EU BIM Task Group).
- Consolidation into best-practice packages that can be taken up by standardization liaisons (e.g., bSI Regulatory Room, CEN/TC442).
- Formalized templates submitted to buildingSMART Use Case Management (UCM) and linked to scalability guidelines.

These best practices directly respond to CHEK Objectives O1–O5 and link the technical innovations with institutional adoption (see Figure 1– Workflow).

Table 2 reports the specific plan for each domain best practice. Structured in three subcategories:

Table 1: Domain Specific best practices for DBP

Domain-Specific Best Practices for DBP

Construction and digital building permit domain applications

Best Practice Title	Standards / Assets Involved	Organisation / SDO	Related Task	Lead Partner	SDO WG / Task Force	Month Report to SDO WGs	Submission of Final Proposal	SDO Policy / Next Step
DBP1 Digital Building Permit Maturity Model	– (method) + KPIs; may reference ISO 19650/CEN TC442	EUnet4DBP / ISO/CEN (liaison as needed)	T1.2; D1.1–D1.2; D6.4	FhI	TBD per chosen venue	M6 (Mar 2023) – M12 (Sep 2023)	Oct 2023 (guide v1); updates through M36	Propose as EUnet4DBP guide; explore ISO/CEN note
DBP2 Template UCM for DBP	UCM, IDS, LoIN, BPMN	buildingSMART	T2.5; WP1/WP4/WP6	BSI (+ partners)	bSI Regulatory Room / UCM	M12 (Sep 2023) – M26 (Nov 2024)	Dec 2024	Approve UCM on bSI platform; publish exemplar
DBP3 DBP best practices & scalability guidelines	IDS, CityJSON/GML, OpenAPI; organisational playbook	EUnet4DBP; possibly ISO 19650/CEN TC442	T6.4; D6.5	FhI	TBD per venue	M30 (Mar 2025) – M36 (Sep 2025)	M37 (Oct 2025)	Feed rule templates to bSI/OGC (IDS, NS1); publish municipal adoption guide

Domain Best Practices	Organizations	Timeline
3	3	2023-2025
		Development and submission

3.1 DBP process mapping and reengineering

Establishing a clear baseline through as-is process mapping (D1.1)[1] was a prerequisite for all pilots. Municipalities documented each step of their workflows, from submission to approval, identifying decision points, data inputs/outputs, and relevant legal references.

Key Enabler: The CHEK Maturity Model and Roadmap (D1.2)[2] guided municipalities in moving from baseline maturity levels towards more advanced, automated workflows. The process map ensured transformations were staged and realistic, preventing disruption.

Lesson: The CHEK process map template enabled consistent mapping across diverse administrative contexts. This comparability allowed gaps, redundancies, and opportunities for automation to be clearly identified.

Pilot Example: In Ascoli Piceno, mapping revealed fragmented data responsibilities across departments. By reengineering workflows, these were consolidated into a unified digital path, improving efficiency. In Prague, BIM-based checks were introduced earlier in the approval chain, allowing designers to receive automated feedback before final submission, reducing late-stage rejections.

Benefit/Impact: Process mapping and reengineering provides a structured foundation for automation, clarified institutional responsibilities, and enables time savings (potentially 80%) while improving decision-making consistency.

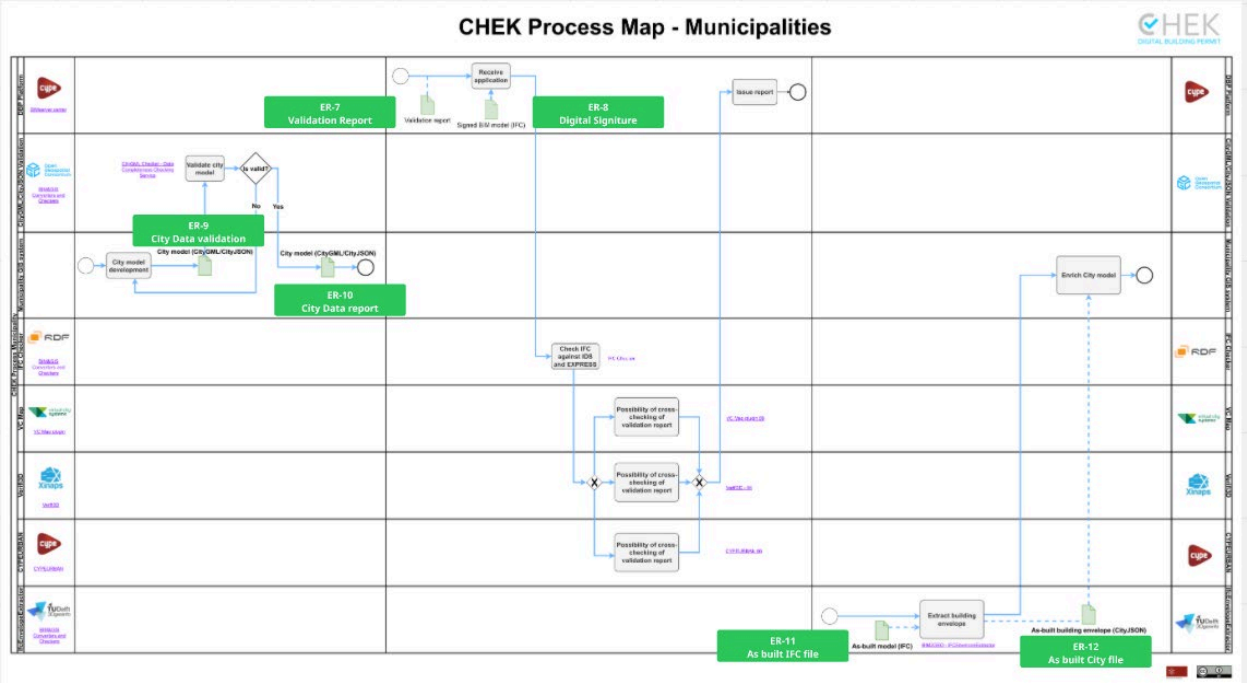


Figure 1 CHEK process and tool workflow: Example of municipalities workflow

[1] Available at: https://doi.org/10.5281/zenodo.7789036
[2] Available at: https://doi.org/10.5281/zenodo.10277474

3.2 Collaborative change management

Use **CHEK Change Management Virtual Assistant** to effectively self-assess digital maturity and plan the transformation strategy. The maturity model offered by CHEK is most successful when integrated with process mapping and analysis enabled by an automated tool like the CHEK VA.

Lesson: Municipalities adopting CHEK needed support to rethink roles, responsibilities, and governance. Change was most successful where leadership, IT, and planning officers worked together.

Key Enabler: The CHEK Change Management Virtual Assistant (D1.3), combined with maturity self-assessments and structured workshops (Tasks 1.3, 1.4), provided guidance on how to manage transition, anticipate barriers, and identify skill gaps.

Pilot Example: Vila Nova de Gaia, with a relatively advanced digital base, used the Virtual Assistant to refine IFC quality checks and strengthen staff training pathways. Municipal officers stressed that early training and political commitment were decisive in building confidence.

Benefit/Impact: Collaborative change management ensures organisational buy-in, reduces resistance to new workflows, and builds a shared vision of digitalisation, aligning technical improvements with administrative readiness.

3.3 Digital-ready regulations

Automation requires regulations that are clear, unambiguous, and structured in a machine-readable way.

Lesson: CHEK showed that ambiguous legal texts and vague terms (“adequate,” “sufficient”) cannot be automated without prior interpretation and formalisation.

Key Enabler: CHEK’s rule interpretation methodology (WP2) used RASE mark-up and AI-assisted extraction to convert written rules into structured conditions linked to IFC and CityGML attributes. While this provided proof-of-concept within the project, CHEK did not aim to comprehensively address regulatory encoding. Other EU projects, such as ACCORD[3], have advanced complementary methodologies in this area, and their results provide important reference points for scaling and consolidating this step across Europe.

Pilot Example: In Lisbon, accessibility and building height rules were digitised. While successful, officers emphasised the need for legal traceability and broader rule coverage for credibility.

Benefit/Impact: Clear and structured regulations enable automatic compliance checking, increasing transparency, reducing interpretation errors, and providing a legal foundation for automation.

As in some cases, or as a possible choice from building permit authorities, regulations will need to be reformulated and adapted to enable digital procedures, here we report some **recommendations for writing digital-ready regulations**, building on the regulation interpretation experience. The list is ordered from low to high maturity.

1) Use short sentences and simple phrasing, with correct use of language.
2) Avoid ambiguities by using quantifiable criteria and measures.

[3] Available at: Scientific papers - ACCORD Partners

3) Avoid referring to external rules (including different governance levels regulations) or customs but rather report all the relevant regulations text close to the main one. A 'building blocks' approach can be used to make the regulations granular and modular and combine them as appropriate, potentially automatically.
4) Refer to specific objects in the city via unambiguous names, or better unique identifiers (especially when moving towards machine-readable regulations, refer to the specific IDs of objects in the 3D city model).
5) Refer to generic objects in the city via their standardized class or property names, consistently with the 3D city model data requirements.
6) Refer to objects in the new building via their standardized class or property names, consistently with the BIM data requirements.
7) Use diagrams and drawings if helpful, to clarify possible ambiguities.
8) Use a formal language or pseudocode to formalize the text for an objective interpretation, fostering the translation to a machine-readable language.
9) Use a standardized machine-readable language whether available.

3.4 Rule checking automation

The move from manual checks to automated validation was central to CHEK's vision. The CHEK architecture (WP4) supports automated checkers for submissions and approvals.

Best Practice: Start with a small set of high-impact checks (e.g., building height, shadow analysis) before scaling to the rest of the rules.

Lesson: Municipalities benefited most when automation focused first on high-impact rules (e.g., building height, shadow analysis, accessibility).

Key Enabler: The CHEK architecture (WP4) integrated IFC/CityGML validation, automated checkers (D4.8), and the IFC digital signature module (D4.5) into a secure workflow.

Pilot Example: In Vila Nova de Gaia, automated solar access checks saved around 23% of review time, with designers pre-checking their models before submission.

Benefit/Impact: Automation reduces review time, increased accuracy, and standardised decisions, directly boosting permitting efficiency and applicant satisfaction.

3.5 Visualisation

Visualisation is critical for building trust in automated permitting.

Lesson: Visualisation made compliance results understandable for both municipal officers and applicants.

Key Enabler: The 3D City Model Viewer (D4.7) and VC Map, as well as 3D models viewers associated to checking tools in general, made it possible to display compliance outcomes in an interactive interface. Visualisation of the geospatial context is currently among the least common features but is considered very helpful.

Pilot Example: In Ascoli Piceno, applicants viewed shading and accessibility outcomes for renovations via VC Map, improving understanding and reducing disputes.

Benefit/Impact: Enhanced visualization improves citizen understanding and therefore strengthens citizen trust, improves submission quality, and reduces conflicts, making the permitting process more participatory.

3.6 Transparency

Transparency is equally vital in automated permitting. It requires not only clear outputs but also clarity about how checks are performed, on what basis, and with which data.

Lesson: Participants stressed that the transparency of workflows and checks is essential. Users must be able to see which regulations were applied, how they were translated into digital rules, and how results were generated.

Key Enabler: Transparency was supported by direct association of rules with their legal text, by clear documentation of how checks were implemented in software (D4.8), and by visualisation tools that allowed officers and applicants to trace results back to the relevant regulation.

Pilot Example: In Lisbon, officers noted that the clear legal reference in the implemented rules made the automated output credible. In Prague, linking BIM checks to documented workflows reassured officers that automation respected regulatory intent.

Benefit/Impact: Transparency strengthes legal credibility, accountability, and trust in the system. It enables municipalities to justify automated decisions, reassured citizens and designers that checks were fair, and laid the foundation for legal acceptance of automated permitting.

3.7 Interoperability – first data handling

Starting from the information needed to check regulations, define standardised data requirements for BIM and GIS and possibly other data, in form of standard data model profiles, by means of supporting standards and solutions, such as buildingSMART IDS and OGC Data Exchange Toolkit.

For defining BIM data requirements, the microservices provided by CHEK can be used, and additional guidelines must be provided, although human-readable, to ensure that the data provided will support reliable analysis and checks.

Lesson: Without interoperability, automation collapses due to inconsistent data formats or missing attributes, i.e., checking tools might not working properly or deliver wrong results whether the input data is not as expected. They should therefore comply to specific data requirements.

Key Enabler: The CHEK IFC (D2.2) and CityGML (D2.3) profiles, data validators interoperability supporting tools (D2.5).

Pilot Example: Prague enforced IFC georeferencing at submission, reducing BIM–GIS alignment issues and enabling smoother Scenario 2 (renovation) checks.

Benefit/Impact: Standardised data handling reduces errors, avoids vendor lock-in, and ensures scalability and cross-city replicability.

3.8 GeoBIM

Integrated 3D geoinformation and BIM in the workflow, for having full advantage of respective tools and representations. Use tools provided by CHEK (IfcGref, IfcEnvelopeExtractor and Geo to BIM) to facilitate the data flow.

Lesson: Combining BIM and GIS is often hindered by different data models, coordinate systems, and levels of detail. CHEK showed that standardised specifications and dedicated tools are necessary to bridge this gap and make integrated workflows feasible in practice.

Key Enablers: Geo-to-BIM and BIM-to-Geo converters (D3.1, D3.3) and IFC georeferencing tool (D3.2), complemented with the GeoBIM best practices (D3.4)

Pilot Example: Benefit/Impact: Increase data appropriateness (i.e. retrieve useful data from the most appropriate datasets), maximise leveraging BIM and GIS tools for their best potential, facilitate data flows reducing modelling efforts, enable new analysis and checks (e.g. city-level checks).

3.9 Modular software and platform architecture

The OpenAPI-based platform allowed the connection of different checkers (urban rule checking, accessibility), demonstrating flexibility across various city contexts. Municipalities differ in maturity, size, and systems; modularity ensured adoption flexibility and therefore scalability. CHEK's approach supports integration with national platforms where applicable, enhancing scalability potential.

Lesson: Modularity allowed incremental adoption, reducing IT risk and avoiding disruption of existing systems.

Key Enabler: The OpenAPI-based CHEK platform (D4.4) supported plug-and-play integration of checkers, validators, and, potentially, national e-permit platforms.

Pilot Example: Lisbon explored the integration of CHEK checkers with its existing national e-submission portal. The pilot demonstrated the potential for such a connection, while also exposing the technical and procedural barriers that currently limit integration with legacy systems.

Benefit/Impact: Modularity enables incremental scaling, supports national integration, and future-proofs municipalities' IT investments.

3.10 Active user involvement and iterative testing

Engaging users continuously ensure that CHEK's tools address real needs. Regular workshops with designers and public officers during tool development help define solutions to actual workflows. Scenarios with both new buildings and renovations highlighted differences in data reuse, performance analysis, and integration needs.

Lesson: Iterative testing exposed workflow differences between new builds (Scenario 1) and renovations (Scenario 2). Involvement of municipal officers was critical to identify local exceptions (D6.4).

Key Enabler: Co-design workshops (D4.2) and iterative pilots embedded municipal and designer feedback into tool development.

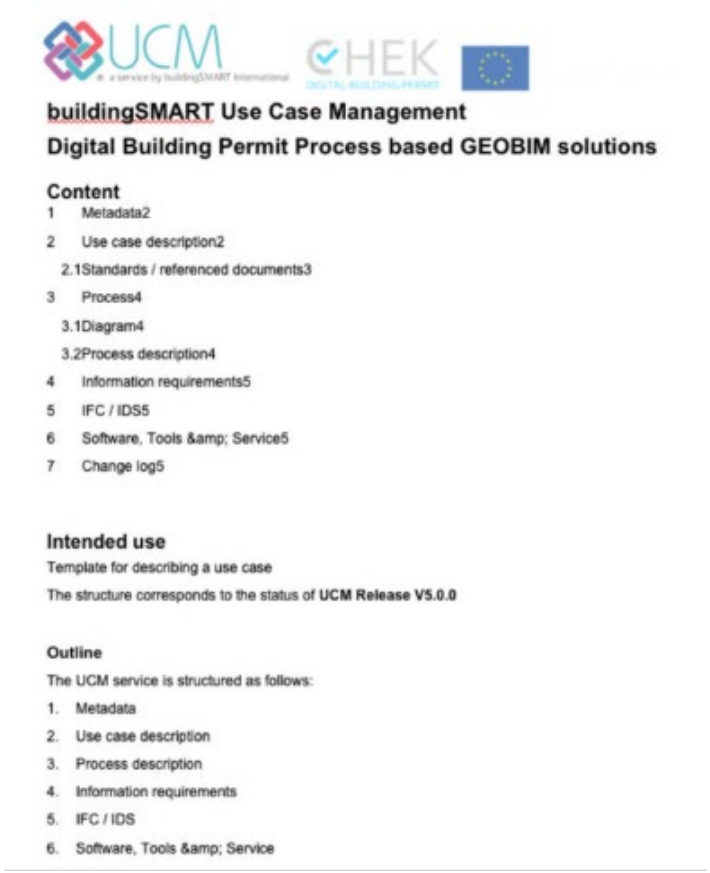
Pilot Example: Vila Nova de Gaia adapted its building height checker after planners highlighted an overlooked local regulation.

Benefit/Impact: Iterative testing increases usability, accuracy, and user acceptance, ensuring solutions reflect real permitting practices rather than abstract workflows. CHEK solutions reflect real permitting practices and build user confidence.

3.11 Template UCM for Digital Building Permit

CHEK developed a **UCM template** for Digital Building Permits, aligning regulatory exchange requirements with the **buildingSMART Use Case Management Service**.

Lesson: Consistent process documentation is essential to ensure that digital permitting workflows are comparable, interoperable, and scalable across municipalities. CHEK demonstrated that aligning the process mapping and data exchanges with buildingSMART standards enables traceability between regulations, data requirements, and software functionalities.



buildingSMART Use Case Management

Digital Building Permit Process based GEOBIM solutions

Content

Intended use

Template for describing a use case

The structure corresponds to the status of **UCM Release V5.0.0**

Outline

The UCM service is structured as follows:

1. Metadata
2. Use case description
3. Process description
4. Information requirements
5. IFC / IDS
6. Software, Tools & Service

Figure 2 Template UCM for digital building permit

Key Enabler: The CHEK UCM template, developed by TUD in collaboration with WP2, WP4, and WP6, built upon existing standards, buildingSMART UCM (V5.0), IDS, and IFC/CityGML exchange formats, to encode the permitting

process. The template was submitted as Appendix 1 for validation within the buildingSMART International (bSI) Regulatory Room.

Pilot Example: The UCM template was tested using pilot workflows from CHEK partner municipalities, documenting pre-check, submission, approval, and as-built update phases. The test confirmed compatibility with the CHEK platform and demonstrated how exchange requirements and IDS packs could be linked via API endpoints.

Benefit/Impact: The Template UCM provides a formalised, standardised framework for representing the digital building permit process. It enables municipalities to reuse and configure workflows according to their national context, facilitates interoperability and traceability, and supports the broader goal of harmonising DBP processes across Europe through buildingSMART validation and recognition.

Best-Practice Steps:

- Define **metadata and ERs** based on CHEK common schema.
- Document processes (pre-check, submission, approval, as-built update) in UCM format.
- Integrate IDS packs and API endpoints as linked artefacts.
- Submit to **bSI Regulatory Room** for community feedback.
- **Expected Output:**
- Formal **UCM template** recognized by buildingSMART.
- Reusable by municipalities to configure their DBP workflows

4. Collected feedback through the lens of best practices

The validation of CHEK solutions did not end with technical demonstrations in the pilots. Feedback was continuously collected from municipal officers, designers, technology providers, project partners and policy experts through the pilot assessments (D6.2–D6.4), the Community of Practice, the Advisory Board, and the Final Public Event (D7.4). To ensure consistency and comparability, this feedback is analysed here through the same best practices framework introduced in Chapter 3.

By linking stakeholder perspectives to the identified best practices, it becomes possible to assess which practices were most strongly validated in real-world conditions, where gaps remain, and what lessons must be carried forward for scaling and long-term adoption. The following tables summarise the feedback lens, the best practice reinforced, and the lesson learned for each of the best practices emerging from CHEK.

Table 2 Collected feedback through the lens of best practice

Nr.	Best practice	Feedback lens	Best practice reinforced	Lesson learned
1	**DBP Process Mapping & Reengineering**	Users appreciated modular tools (CYPE, VC Map, Solibri), but also requested simplified, unified **workflows**.	Mapping and reengineering must not only digitise steps but also ensure regulatory content is usable for automated checks.	Process reengineering should always include legal traceability in national language as a foundation.
2	**Collaborative Change Management**	Both the CoP and Final Event participants stressed training, staff skills, and leadership commitment as barriers.	Collaborative change management (CHEK VA + workshops) is essential.	Change management must include role-specific training and early political buy-in, not just technical staff workshops.
3	**Good Regulations**	Participants highlighted missing rules, unclear coverage, and demand for legal credibility.	Automation requires clear, unambiguous, machine-readable regulations.	"Good regulations" means not only structured in IFC/CityGML but also legally anchored, ensuring confidence in automated outputs.
4	**Workflow Automation**	Tools were found useful and somewhat easy, but users called for more stability and broader rule coverage.	Start with high-impact checks (height, shading, accessibility).	Workflow automation must be progressive and modular, demonstrating impact early, while scaling up to more complex domains.
5	**Communication & Transparency**	Respondents praised BIM–GIS integration and 3D viewers (VC Map, CYPE), but asked for collaboration features (annotations, partial approvals).	Visualisation builds trust.	Transparency also requires two-way interaction (reviewer - designer), not just one-way compliance visualisation.
6	**Interoperability-First Data Handling**	Integration of GIS and BIM was repeatedly identified as a most valuable feature.	IFC + CityGML + converters are a cornerstone.	Stakeholder validation shows interoperability-first handling is non-negotiable for scaling.

7	**Modular Software and Platform Architecture**	Users appreciated modular tools (CYPE, VC Map, Solibri), but also requested simplified, unified workflows.	Modularity supports scaling.	Modularity must be paired with workflow consolidation to avoid fragmentation and "designer-first" perceptions.
8	**Active User Involvement and Iterative Testing**	Respondents called for more municipal involvement and earlier testing with authorities.	Co-design workshops are essential.	Iterative testing should prioritise municipal staff first, to ensure adoption readiness, not only designer tools.

5. Scalability Guidelines

Scaling the CHEK toolkit requires municipalities to act along three dimensions: (1) ensuring organisational readiness, (2) implementing technical steps incrementally, and (3) tailoring strategies to local contexts. These guidelines synthesise lessons from the pilots (D6.2–D6.4), feedback from the Community of Practice, Advisory Board and Final Event, and insights from the Exploitation Plan (D7.3) as well as the lessons learnt throughout the whole project (Annex 1).

5.1 Organizational readiness

Begin with maturity assessment using CHEK tools (D1.2-D1.5).[4]

Secure cross-departmental commitment, including IT, urban planning, and legal units.

Digital permitting transformation starts with governance and capacity, not technology.

Steps for readiness:

1. **Maturity assessment:** Apply the CHEK Maturity Model (D1.2) to establish baseline capabilities in process, organisation, technology, and information.
2. **Leadership and commitment:** Secure political and executive support to enable cross-departmental cooperation (planning, IT, legal units).
3. **Structured change management:** Use the CHEK Change Management Virtual Assistant (D1.3) and workshops (Tasks 1.3, 1.4) to plan transformation, anticipate resistance, and guide staff through change.
4. **Capacity building:** Start training early with CHEK Wiki and glossary (D5.1), training resources chosen based on roles and starting knowledge (D5.3, D5.4), workshops (D4.9), and scenario-based tutorials tailored to municipal staff.

Pilot lesson: In Ascoli Piceno, early commitment allowed a municipality with very low maturity to envision digitalising up to 80% of workflows once leadership and staff were aligned.

Impact: Building organisational readiness ensures that technical deployment is sustainable, preventing the common pitfall of “technology-first” approaches that fail due to organisational inertia.

5.2 Technical implementation steps

CHEK’s modular and standards-based design supports stepwise technical adoption, avoiding disruptive system overhauls.

Implementation pathway:

[4] Tools available at: https://doi.org/10.5281/zenodo.17236331 and https://doi.org/10.5281/zenodo.10277474

1. **Map the local building permit process and translate it to a digital building permit process:** it will be the reference to select the most suitable components to be integrated into the building permit platform architecture.
2. **Define regulatory rules:** Prioritise encoding of high-impact rules (e.g., building height, solar access, accessibility) using CHEK's rule interpretation methodology (WP2) or other suitable methodology to be found in literature.
3. **Set up BIM/GIS workflows:** Establish regulatory requirements-based IFC (D2.2) and CityGML (D2.3) profiles, by leveraging, respectively, the buildingSMART IDS standard, associated to microservices (as developed in CHEK) and additional guidelines as needed (D2.2) and the OGC Data Exchange Toolkit (D2.5). Identify where the two technologies can provide best advantage and the conversion points between each other (the CHEK process workflow can be a reference in this respect). Use the Geo-BIM conversion tools (D3.1, D3.3) and IFC georeferencing tool (D3.2) to support those steps and consistent data flow through the different tools.
4. **Integrate tools:** Connect all the tools serving the different steps of the workflow, including automated checkers (D4.8), other validators and interoperability-supporting tools (D2.5), and the IFC Digital Signature module (D4.5) into municipal workflows through the CHEK Platform (BIMserver.center and CYPE Validation) via APIs available for programming through OpenAPI-compliant specification (D4.3, D4.4).
5. **Pilot test cases:** Run a controlled scenario to validate workflows, test stability, and gather feedback.

Pilot lesson: By following such steps in all the CHEK pilots, it was possible to use the same approach throughout the four cases. In the final interviews, an operator from the municipality of Vila Nova de Gaia declared: "Although we looked so diverse at the beginning, we could reuse the same components. We are not so different, after all".

Impact: A stepwise pathway reduces risk, ensures incremental value delivery, and builds trust in automation among staff and applicants.

5.3 Adaptation strategies

Municipalities differ in size, maturity, and national context. CHEK's modular toolkit allows for tailored adoption.

For small municipalities / low maturity:

- Adopt hosted cloud solutions to avoid heavy IT investments.
- Use simplified training materials and preconfigured rule sets.
- Focus first on digital submission and pre-validation checks to build early confidence.

For large municipalities / high maturity:

- Integrate CHEK modules into existing e-permit or national DBP platforms using the OpenAPI approach.
- Scale encoded regulations to advanced domains (e.g., energy efficiency, microclimate, fire safety).
- Leverage standards-based interoperability to connect existing BIM/GIS infrastructures.

For national or cross-border scaling:

- Promote CHEK IFC/CityGML specifications (D2.2, D2.3) as reference standards.
- Leverage EUnet4DBP to share rulesets and ensure alignment across municipalities.
- Ensure tools are localised linguistically and legally, with traceability to national regulations.

Pilot lesson: Lisbon and Vila Nova de Gaia showed that integration with existing portals is feasible, but effectiveness depends on broader regulation coverage and stable workflows.

Impact: Adaptation strategies allow CHEK to scale from small towns to large metropolitan authorities, while ensuring alignment with national DBP initiatives and European interoperability goals.

6. Recommendations for future uptake

The CHEK pilots, stakeholder feedback, and exploitation analysis highlight clear pathways for the long-term adoption of digital building permitting in Europe. These recommendations target municipal, national, and European levels, ensuring that lessons from CHEK translate into scalable and sustainable practices.

6.1 National DBP programs as reference models

- Adopt CHEK methodologies (process mapping, maturity assessment, rule encoding, modular tool integration) as reference models for national DBP strategies.
- Ensure national programs incorporate open standards (e.g. IFC, CityGML/CityJSON, IDS, OpenAPI, OGC APIs) to guarantee interoperability and avoid vendor lock-in.
- Integrate CHEK's Maturity Model and Roadmap into national digitalisation policies, ensuring staged and achievable transitions.

Stakeholder link: Final Event participants confirmed that legal traceability and alignment with national law are key. National programs should therefore anchor automated checks to official regulations in local languages.

6.2 Strengthening standards and interoperability

- Encourage standardisation bodies (buildingSMART, OGC, ISO, CEN) to formalise CHEK specifications as foundational templates for DBP.
- Promote wider uptake of IFC and CityGML profiling strategy, ensuring that BIM and GIS-based analysis reliability, as well as integration, is supported by international standards.
- Support development of shared rule libraries, so municipalities across Europe can reuse validated, digital-ready, encoded regulations.

Stakeholder link: The CoP and AB underlined that CHEK's standards-first approach is its strongest asset for scalability.

6.3 Promoting knowledge exchange between municipalities

- Expand networks like EUnet4DBP to act as a European knowledge hub for DBP best practices.
- Encourage municipalities to form regional clusters for adopting CHEK together, reducing costs and resource barriers.
- Promote peer-to-peer exchanges on regulation encoding, workflow integration, and training practices.

Stakeholder link: Final Event respondents saw CHEK as an inspiration for future work and called for greater municipal involvement in shaping tools. Networks like EUnet4DBP can provide this participatory space.

6.4 Investment in training and capacity building

- Develop role-specific training packages for municipal staff, planners, IT officers, and legal departments.
- Integrate CHEK training into professional development programs for architects and engineers, so designers are prepared for pre-checking workflows.
- Increase dissemination and communication efforts, targeting smaller municipalities that lack awareness or skills.

Stakeholder link: Training was identified as the second most pressing barrier (after legal change) by 10 of 14 Final Event respondents.

6.5 Summary of recommendations

Table 3 Summary of recommendations

Level	Recommendation	Expected Impact
Municipal	Begin with maturity assessment; pilot high-impact rules; invest in training.	Gradual, low-risk adoption of DBP workflows.
National	Adopt CHEK methodology as DBP reference model; ensure legal traceability.	Interoperable, scalable national DBP platforms.
European	Support standardisation of CHEK specifications; strengthen EUnet4DBP; provide further financial support to implement the next steps.	Cross-border scalability and reduced fragmentation.
All levels	Expand rule libraries, consolidate workflows, and build training pipelines.	Move to full production-ready DBP systems.

7. Next steps - Bridging prototype to production

To move from overall TRL 7 to TRL 9 and actual uptake, the next steps to progress the CHEK results and integrate the missing steps will be:

1. **Expand rule coverage** – encoding more rules across domains (accessibility, energy, environmental, fire safety). Complementary or parallel to this step, the regulations might be improved and transformed to better align to digital tools functionalities and potential.
2. **Workflow consolidation** – advance the central platform to higher TRLs, to smoothen the workflow management and improve components integration, and connect to the local, legally-bounded platforms.
3. **Collaboration features** – enabling iterative designer–reviewer interaction (annotations, partial approvals) through the platform or directly in the checking tools.
4. **Multilingual support** – ensuring user interfaces and automated checks link to national legal texts and can be easily understood by local stakeholders.
5. **Policy anchoring** – recognition of digital signatures and automated checks in administrative law (eIDAS compliance).

8. Conclusions

The CHEK project developed a toolkit of solutions to support the digitalisation of building permitting, combining process mapping, maturity assessment, interoperability specifications, automated checking tools, and collaborative change management approaches. These solutions were demonstrated in close cooperation with municipalities in Ascoli Piceno, Lisbon, Vila Nova de Gaia, and Prague, across scenarios covering both new constructions and renovations. The WP6 pilots in Ascoli Piceno, Lisbon, Vila Nova de Gaia, and Prague confirmed both the feasibility and the challenges of this ambition.

From these demonstrations, a set of best practices was identified, together with feedback from pilots, the Community of Practice, the Advisory Board, and the Final Event. These insights confirmed the value of CHEK's standards-based and modular approach, while highlighting the need for broader rule coverage, workflow consolidation, transparency, localisation, and role-specific training.

This deliverable brings together the lessons learned, the scalability guidelines, and the recommendations for future uptake. It outlines the next steps needed to move from pilot-tested prototypes towards wider implementation and adoption of Digital Building Permit processes across Europe.

9. References

9.1 Project Deliverables

D1.1 – CHEK DBP Process Map
Provided a baseline as-is process map template used across pilot municipalities.

D1.2 – Maturity Model and Roadmap
Defined staged pathways for digital permitting transformation and maturity assessment.

D1.3 – CHEK Change Management Virtual Assistant
Supported municipalities in self-assessing maturity and planning transformation strategies.

D2.2 – CHEK IFC Specification
Defined IFC profiles adapted for DBP compliance checking.

D2.3 – CHEK CityGML Specification
Defined CityGML profiles enabling BIM–GIS interoperability.

D2.5 – Exchange Information Requirements for DBP
Defined data exchange requirements supporting automated checks.

D3.1 – Geo to BIM Tool Procedure
Provided methods and tooling for converting geospatial data into BIM-compatible formats.

D3.2 – IFC Georeferencing Tool
Enabled consistent spatial referencing of IFC models to support integration with GIS.

D3.3 – BIM-to-Geo Envelope Extractor
Extracted building volumes for GIS-level analyses.

D3.4 – GeoBIM Best Practices
Summarised workflow recommendations for integrating BIM and GIS models.

D4.2 – Design Sprint Results
Documented co-design workshops that informed tool requirements and usability.

D4.3 – CHEK Process and Data Management Platform
Integrated IFC/CityGML validation tools and automated checking workflows.

D4.4 – OpenAPI for CHEK Platform and Integration Manual
Specified the OpenAPI approach for connecting modules and external systems.

D4.5 – IFC Digital Signature Module
Provided secure digital signing of BIM models for submission and approval workflows.

D4.7 – 3D City Model Viewer for Pilot Use-Cases
Delivered visualisation tools to support communication and transparency.

D4.8 – Checking Tools for CHEK Regulations
Implemented rule-checking components for pilot scenarios.

D4.9 – Software Documentation and Workshops
Offered technical guidance and training sessions for end users.

D5.1 – Wiki Training Materials and Glossary related to DBP
Compiled terminology and training resources to support user capacity building.

D6.2 – Results Demonstration Scenario 1
Reported outcomes of pilot demonstrations for new construction projects.

D6.3 – Results Demonstration Scenario 2
Reported outcomes of pilot demonstrations for renovation projects.

D6.4 – Report on Pilots' Assessment and Stakeholders' Feedback
Analysed stakeholder evaluations of CHEK tools, scenarios, and user experiences.

D7.3 – Exploitation Plan
Outlined market uptake, stakeholder segments, TRL status, and sustainability pathways.

D7.4 – Final Event and Community of Practice Report
Collected final stakeholder feedback and validation of project outcomes.

9.2 List of Figures

9.3 List of Tables

9.4 List of used abbreviations

AEC – Architecture, Engineering and Construction

API – Application Programming Interface

BCF – BIM Collaboration Forma

BIM – Building Information Modelling

bSI – buildingSMART International

CoP – Community of Practice

DBP – Digital Building Permit

EIR – Exchange Information Requirements

FAIR – Findable, Accessible, Interoperable, Reusable

GIS – Geographic Information System

IDS – Information Delivery Specification

IFC – Industry Foundation Classes

KPI – Key Performance Indicator

LoD – Level of Detail

OGC – Open Geospatial Consortium

TRL – Technology Readiness Level

WP – Work Package

ANNEX 1

Evidence and scalability insights from the CHEK project

The CHEK pilots confirmed that the Digital Building Permit (DBP) toolkit can execute a full end-to-end digital workflow in four diverse municipalities. Moreover, scalability requires assessing exploitation potential, technical readiness, openness, documentation, user experience, and compliance with standards. This chapter synthesises findings from the demonstrations (D6.2, D6.3, D6.4) and aligns them with the exploitation plan (D7.3).

Exploitation potential

The CHEK toolkit demonstrated two complementary values:

- Transformative value in lower-maturity contexts (e.g., Ascoli Piceno, Prague), where CHEK provided a structured pathway to digitalisation. In Ascoli, the potential digitalisation of up to 80% of workflows was identified.
- Enhancement value in higher-maturity contexts (e.g., Lisbon, Vila Nova de Gaia), where CHEK added pre-checking, IFC quality assurance, and transparent visualisation.

According to the Exploitation Plan (D7.3), CHEK addresses three core markets:

1. Municipalities and permitting authorities – seeking to ease permitting processes and increase transparency.
2. AEC professionals – designers and contractors benefiting from pre-checks and fewer rejections.
3. Software developers – able to extend their services by integrating CHEK modules (e.g., CYPE, Solibri, VC Map).

Scalability insight: CHEK is not a single product but a modular toolkit with multiple entry points, making it adaptable to both small towns and large cities.

Standardised data and profiles

CHEK strongly prioritised openness and interoperability, especially by relying of open standards and providing modules and profiles at a rather granular level, so that they could be easily reused by others and composed in the desired architecture:

- **Standards compliance:** The profiles to use the standard data models (IFC ansd CityGML) were specified at a highly granular level and reused in the desired composition for the different cases. Standard solutions (i.e., IDS and OGC Data Exchange Toolkit and OGC building blocks registry) were leveraged to enchance interoperability and reusability.
- **FAIR principles:** Data outputs designed to be findable, accessible, interoperable, and reusable (D8.3).

Pilot evidence: All the municipalities could use the same tools, accessed from the same platform to check their own regulations. they could choose among different tools to check different regulations, according to how the demonstrations were designed. Standards enabled interoperability across diverse IT ecosystems. Municipalities confirmed that open standards reduce vendor lock-in and ensure future-proof scaling.

Scalability insight: CHEK's standardisation and modularity, relying on open standards whenever possible, ensures replicability across national contexts. Assuming granularization of local regulations (e.g. develop regulations as a composition of atomic legal sentences to describe the needed checks) and development of related data profiles and checking tools, scalability gets even wider.

Modular software architecture

CHEK strongly prioritised openness and interoperability, especially by relying of open standards and providing modules and profiles at a rather granular level, so that they could be easily reused by others and composed in the desired architecture:

- **Open source or modular services:** all the pieces of software were able to connect to the central platform represented by BIMserver.center through APIs defined according to the OpenAPIs specification and following open standards. This allowed the municipalities to use the tools in which the respective regulations were implemented, or to test different tools as desired. Moreover, some of the services and tools (e.g. the IfcEnvelopeExtractor) are provided as OGC Process API, providing a further step of openness and interoperability, allowing even easier tools composition.

Scalability insight: CHEK's modular software architecture, built on open standards and accessible APIs, enables incremental adoption and integration with national DBP platforms, ensuring scalability and long-term sustainability of municipal digital infrastructures.

Educational resources: Software documentation and training

CHEK delivered a substantial knowledge base, including tutorials and documentation:

- CHEK Wiki and glossary (D5.1) for achieving a shared understanding and terminology.
- Modular software documentation (i.e., one video per tool execution steps, short duration) and workshops (D4.9) with practical demonstrations.
- Video tutorials supporting onboarding during pilots (D6.4).
- Training courses tailored for different kinds of audiences.

Scalability insight: Actors and context reaching different levels of awareness, skills and knowledge, as well as familiarity with the involved BIM and GIS tools can have advantage of the materials provided, useful to integrate the knowledge gaps or needs for support flexibly and to the point.

Language

Language was identified as a barrier to adoption.

- CHEK tools were developed in English, while regulations and municipal workflows will require native-language interfaces and legal traceability.
- Municipal officers emphasised that legal acceptance of digital checks depends on linking automated results to official legal texts in the national language.

Scalability insight: Multilingual user interfaces and adaptation to local contexts (including translation to local languages) will be among the next steps for broader uptake.