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Performance Based Specification of Wood – Project CLICKdesign

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Abstract. *This paper introduces the ForestValue research project CLICKdesign – delivering fingertip knowledge to enable service life performance specification of wood. The consortium is working on a primary innovation to move from the complex, fragmented and general to the easy-to-use, consolidated and specific by provision of a digital tool for specifiers. Other materials tackle this and provide designers and architects with software. The specification of performance of wood products is complex and fraught with inconsistency and requires use of multiple platforms for data, experience, standards and national recommendations. CLICKdesign will provide a tool that has within it the decades of research, the complexity of the standards specification systems and the variation of approach due to tradition, materials and culture across Europe and beyond. A simple tool for nonexpert public users will be available as well as a tool accessible to professional users that will be refined with industry to ensure relevancy and accelerate uptake and use.*

Keywords: *Durability-Based Design, Knowledge Transfer, Modelling, Performance, Service Life Planning.*

1 Introduction

Concrete, steel and polymeric sectors deliver software to architects and students enabling easy performance-based specification and design. It also enables easy teaching of design best practice and informs learning gathered by product manufacturers. This does not happen for wood comprehensively in Europe, though specific initiatives e.g. UK Structural Timber

Association guidance (www.structuraltimber.co.uk) and the German Carpenter Association's Guideline on Building Facades, Terrace decking, and Balconies (BDZ 2011, 2016) do exist. In addition, technical specifications are integrated into increasingly used Building Information Modelling (BIM) and life cycle analysis (LCA) which includes service life data. Service life planning and performance classification are thus core issues in the building sector underpinning material/product specification and use. The absence of durability performance-based specification for wood is currently a limit of opportunity. Well-functioning 'performance models' are essential to predict the service life and functionality of buildings.

2 Project CLICKdesign Context

2.1 Analysis of the Problem

The established specification of wood is not performance based, historically standards refer to ineffectual terms to bridge the performance gap such as "a reasonable working life". Wood engineers utilising Eurocode 5 find the ineffectual language doesn't stand scrutiny and is of little value. Awareness of the cultural legacy of wood in construction around us, traditional uses and skills are constant reminders of the enduring possibility of wood if knowledge is applied, including knowledge of species and material qualities, knowledge of design details and construction skills, knowledge of local conditions, climatic or other challenges. This knowledge is fragmented, localised and in some cases difficult to analyse and use especially by non-wood experts. This is the problem. The solution is to put this knowledge at the fingertips of the specifier, in their language so more can meet their ambitions to deliver low carbon construction, through performance based design with wood.

The existing decision logic of specification of durability, and implied performance, considers first the suitability of a timber species for use in construction. This first considers the natural durability of the chosen timber species (EN 350: 2016) and notes the intended end use (EN 335: 2013), *e.g.* Use Class 4 for a fence post. EN 460: 1994 compares the requirements of Use Class with the natural durability and indicates whether natural durability is sufficient for the end use or whether preservative treatment is required. The European Standards related to specifying preservative treated timber, EN 351-1: 2007 and EN 351-2: 2007 require the specification to be written in terms of the end results of the treatment process i.e. penetration and retention in the wood of a preservative formulation found to be effective in a series of standard biological test methods laid down in EN 599-1: 2013. The specification of service life has evolved around the end results achieved following preservative treatment with service life referred to in an unquantified and ambiguous way using terms such as "reasonable working life" or "satisfactory performance". Standards that started to define desired service lives were a step in the right direction as the desire for information on performance of wood products grew in part buoyed by the application of LCA for construction products that pivots on their service life requirements. In Germany, France and UK there are national documents that set out frameworks for performance. In the UK the British Standard BS 8417: 2011 sets out a framework for specifiers to interpret the European standards and to base specifications on penetration and retention requirements linked to treated products and 'desired service life'.

The established wood species and treatment combination for a specific use class works well but has gaps that miss many additional opportunities for timber in construction through good design detailing, the aesthetic performance, other tools to enhance natural properties, the impact of surface cracks on performance, surface roughness and the more subtle moisture dynamic of the wood material.

Different types of performance models have been established for various building materials but cannot be transferred to wood-based materials. For performance modelling of wood products biological agents need to be considered with particular attention for mould, decay fungi, termites and other insects as well as the strong societal values of regional vernacular, skills and traditions that only wood as a material brings. Different approaches to adequately reflect the influence of biotic and abiotic factors on the performance of wood have been reviewed and evaluated (Brischke and Thelandersson 2014) with respect to their usability in the building trade. They found that efforts in developing performance models for both fungal decay and mould growth have been intensified in recent years (*e.g.* MacKenzie *et al.*, 2007, de Freitas et al. 2010, Viitanen *et al.*, 2010, Isaksson *et al.*, 2013, Niklewski *et al.*, 2016). A high heterogeneity among the numerous attempts became visible, different strategies have been followed, and were roughly distinguished according to the respective objectives, governing variables (*e.g.* mass loss, strength loss, remaining strength, decay ratings, service life, aesthetic appearance), data sources and the resulting level of accuracy.

A framework of how exposure, dimension, design details, and the material-intrinsic ability to take up and release water can be linked to model the moisture risk in wood products and thus performance is the central need. First attempts prepared using various dosimeter models were made in previous European research projects, namely the WoodWisdom-Net projects WoodExter and DuraTB, the Swedish WoodBuild program, and the FP7 project PerformWOOD. Good progress has been made during recent years in service life planning and performance prediction of wood-based components and structures, but as repeatedly became evident, the complexity of performance is still not captured in these processes.

The cross-links and interactions between exposure models, different decay and degradation models, and material resistance models need to be deeply elaborated to allow their utilization for comprehensive performance prediction. Furthermore, the degradation processes described and forecasted with the help of models need to be assessed for the respective purpose. Hence, one needs to distinguish between aesthetic performance, functional performance, mechanical performance and other aspects of performance (Jones and Brischke 2017). In particular, the effect of fungal, bacterial or insect damage on the overall mechanical stability of wooden structures is still neither fully understood nor adequately modelled for engineering purposes.

2.2 Beyond the State-of-the-Art

Project CLICKdesign is shown schematically in Figure 1 and includes:

- Forecasting surface aesthetic changes developing the kinetic and/or intensity of such changes due to location, microclimate, architectural design and materials used.
- Development of damage spatial distribution significance on mechanical performance. Studying spatial distribution of fungal decay and its interaction with moisture transport and resulting gradients in buildings.
- Development of a termite/insect performance measure for the first time in Europe.

– Robust integrated performance classification based on the whole set of external parameters for the first time the foundation established for decay, material and integrity aspects, aesthetic limits and performance and termite/insect performance aspects.
– Providing a CLICKdesign tool that utilises European standards, the latest research findings and wood databases such as the IRG Durability Database (http://www.irg-wp.com/durability) and puts it at the fingertips of specifiers and users. This will increase market confidence with users for selecting wood as a reliable product and enhance an optimised performance of timber in the built environment.
– Features wholly not integrated into specification now. The significant variations due to climate change present changes to exposure dose for wood products and the distribution and locations of wood destroying organisms e.g. termite risk zones in Europe.
– Inspiring new wood and wood-based products using the tool, supported by training outreach, and creating business opportunities for industries to innovate.

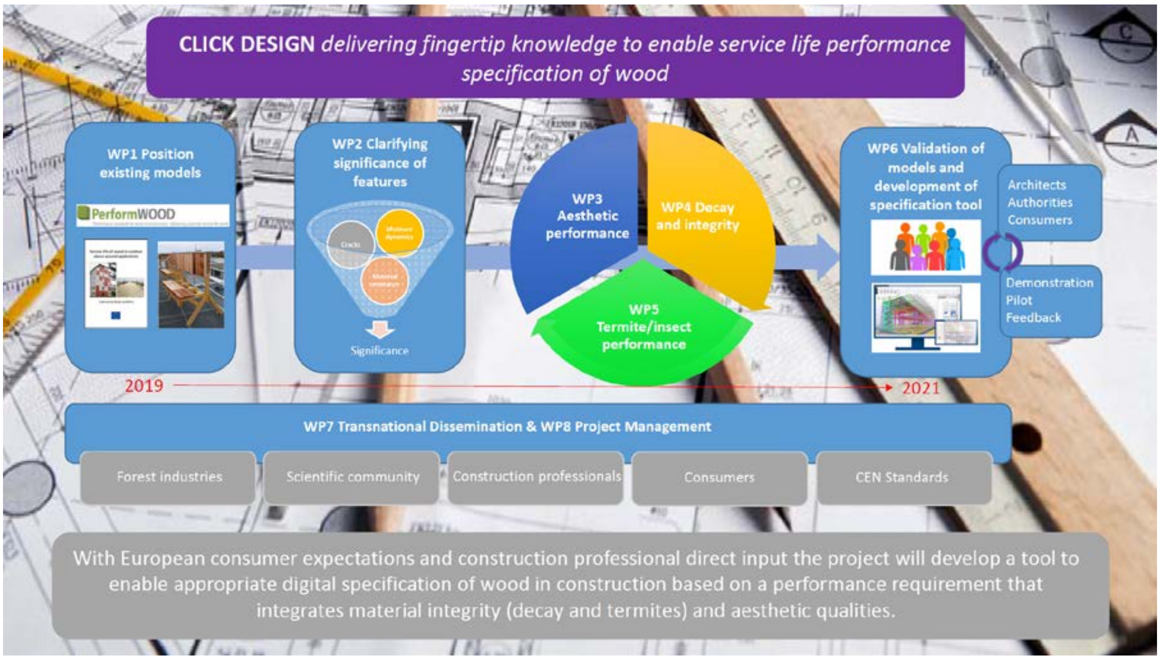

Figure 1. CLICKdesign project schematic showing proposed work packages.

The project builds on the foundations of the basic models and previous research work that comprise the existing knowledge landscape (Figure 2). Existing performance classification research has drawn together aspects of design detailing, climate and material and looked at forecasting performance compared to performance observed for construction products in buildings across Europe (PerformWOOD, WoodExter). Whilst this worked well as a rule of thumb it was missing two key features: aesthetics and insects.

In addition, modelling the effect of fungal decay on mechanical properties of wooden structures is being made, going beyond the simple limit states of previous work e.g. 'onset of decay' or 'failure'. Including these features has never been done before alongside the relatively mature model position that we have established in Europe for materials, strength, decay, design and performance.

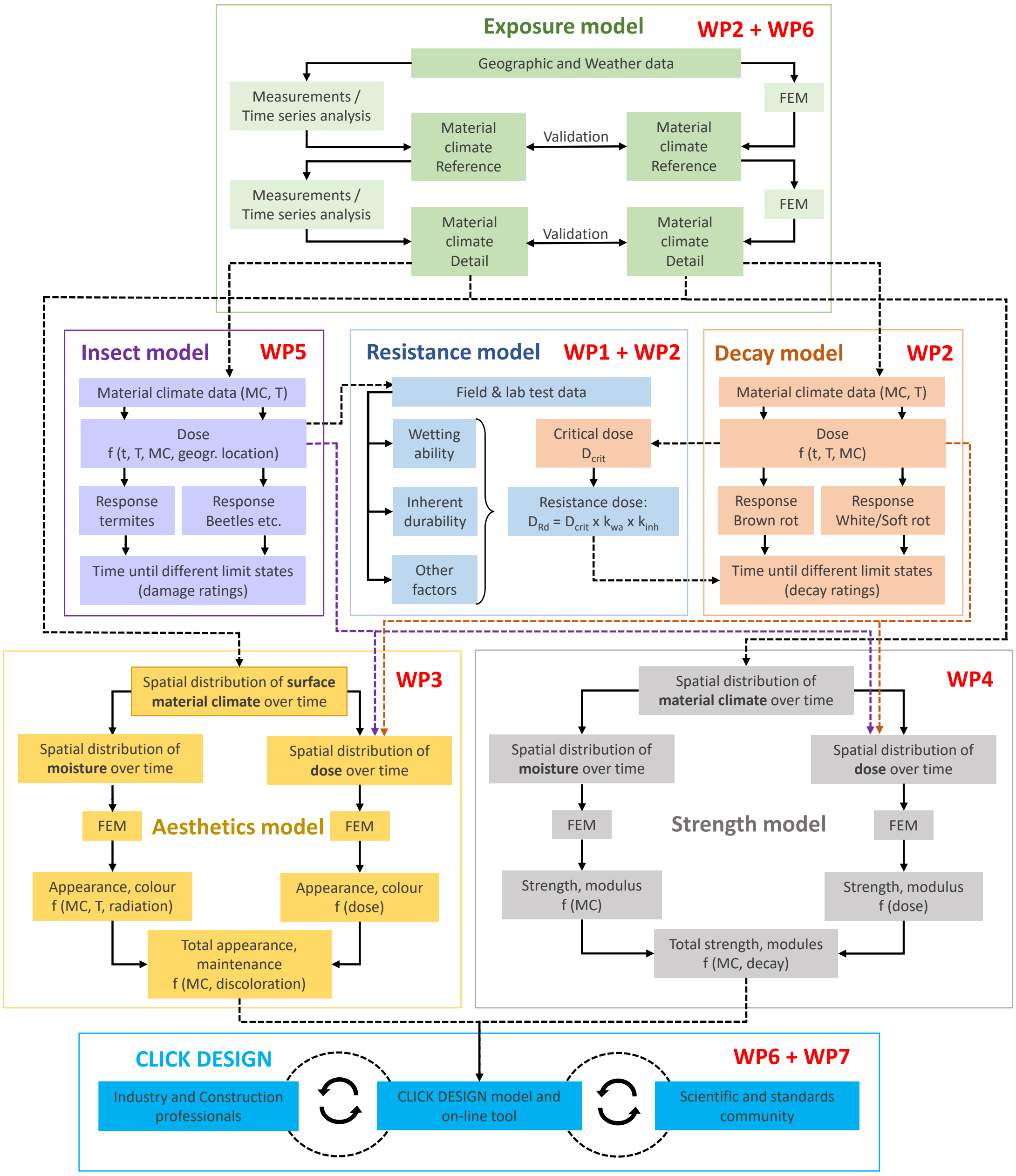

Figure 2. Different elements of performance modelling addressed in CLICKdesign.

For exterior cladding and other applications of wood and wood-based products the acceptance of changes in aesthetics (weathering, colour change, mould) is the key customer parameter (Gobakken 2009, Gellerich *et al.*, 2017). Forecasting of surface changes in terms of discoloration, roughness, overall appearance is therefore indispensable and needs to be linked with other performance models. This is especially critical for Use Class 3 (outdoor above-ground) wood performance classification and for pan-European uptake.

Different parameters need to be taken into account in order to define the risk for a wooden element of being degraded by biological agents, including termites and other insects. Subterranean termites are widely distributed in warm climates across the countries of southern Europe, both in rural and in urban areas. The most serious harm caused by subterranean termites to buildings is the degradation of the wooden elements, in particular those ensuring the integrity of the building such as the timber frame, load-bearing elements and structural panels.

Key to the success for CLICKdesign is that the tool finds application across Europe's rich diversity of geographic, climatic and cultural regions. The integration of climatic conditions (meso, macro and micro) into the models is fundamental and one approach where this is being tackled. The weather through experiences in projects such as DuraTB and Woodlife are translatable into microclimate in the wood and its response. A relationship connecting climate parameters to the material climate makes it possible to analyse a wide range of regional climates through use of open meteorological databases such as ECMWF www.ecmwf.int. Dosimeter approaches developed to describe the interrelationship between material-climatic parameters (exposure dose), material-specific resistance (resistance dose) and wood degradation (response) can then be used to study the regional-specific performance. The same methodology is also be employed for predicting degradation by termites and other insects. For that purpose, input variables need to be different and will be sought from existing field test data and short-term resistance tests performed within CLICKdesign. Success will be possible using a structured approach that couples models and enables direct localisation for the user. In addition, factors that differ between countries and regions of Europe we are cognisant of fostering the different traditions of use of wood, differences in expectations on service life and warranties, differences in cultural aspects towards product maintenance and language accessibility.

2.3 Project Facts

Project CLICKdesign started 1 March 2019 and runs for 3 years. A consortium of 8 European organisations is delivering the core research components of the project comprising building physics, wood science, BIM, service life modelling and entomology. It also has a direct link to the expert research team in FPI Innovations, Canada to look at global application and a diverse pan-European industry group of 18 members who will help pilot and bring together the modelled components of performance of wood in use to develop an open source tool.

2.4 Project Highlights to Date

Whilst additional DBMC papers (*e.g.* Digital transformation of biological processes and building design theory) are reporting on some of the detail a summary of highlights against work package (WP) are shown in Table 1.

3 Conclusions

The specification of performance of wood products is complex and fraught with inconsistency and requires use of multiple platforms for data, experience, standards and national recommendations. CLICKdesign will provide a tool that has within it the decades of excellent research, the complexity of the standards specification systems and the variation of approach due to tradition, materials and culture across Europe. The tool will be accessible to professional users and will be refined with industry to ensure relevancy and accelerate its uptake and use. The project supports "fit for purpose" product specification and enables specifiers and users to understand the impact of their choices on performance.

Table 1. Summary of project CLICKdesign highlights up to November 2019.

Work Package	Achievements
1 Position existing models	A full review of existing models has been completed and an analysis extracting useful features completed.
2 Clarifying missing features	Research on missing features from existing models and testing of these features that impact on performance is underway including splash water effects, cracking, microclimate, vegetation and driving rain.
3 Aesthetic performance	Definition of a numerical parameter for aesthetic quality is underway alongside limit state definitions. A tool is ready that can be used to simulate changes in visual appearance due to weathering for facades.
4 Decay and Integrity	Hygrothermal models are being refined to include aspects of the spatial distribution of decay in wood to understand impact on structural integrity and enable deeper finite element analysis.
5 Termite/insect performance	A measure of the performance of relevant construction materials with regards to insect degradation is being laboratory tested to help define the performance measure.
6 Validation of models and specification tool	A specification tool has been developed to enable focus on its adaption and the inclusion of aesthetic and insect models.
7 Dissemination	Through conferences and articles over 15,000 construction professionals, regulators and product manufacturers have been reached.
8 Project management	A new self-funding partner the University of Vigo has joined the project which brings new expertise and includes Spain into our European reach.

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