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TREE-FAÇADES
Integrating trees in the building envelope as a new form of Façade Greening

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ABSTRACT
This research aims to look at the possibility of making trees a part of the building, especially façades, to improve the thermal comfort in and around the building. Furthermore, integrating trees in building envelopes could generate new aesthetic and spatial possibilities for the design. By building on the methods of research by designing and research through drawing, tree façades are investigated in different scenarios concerning the building-tree interaction. The outcome of the study is that tree façades could become a new approach for designers of a so far unexplored, aesthetical, and microclimatic aspect of architecture. When implemented in an urban planning scale, tree façades could create networks of habitats that are otherwise typically fractured in the urban fabric. The idea of tree façades is somewhat new and revolutionary not only for future architecture in Germany but for other countries in the world. This basic research could open more doors in architecture and infrastructure. It could contribute to reformulating the way we merge our built environment with natural systems.

KEYWORDS
tree façade, building greening, living architecture, sustainable design, urban heat island

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Architects and landscape architects are confronted with numerous challenges in developing spaces for humanity and biodiversity in the current global warming and climate change crises. The concern of the research project at hand is to address strategies for mitigating rising temperatures in the urban fabric. Nearly half of the world's population lives in cities (Ritchie et alii, 2018), and cities account for three-quarters of the European population (Eurostat, 2016). It takes an increased amount of energy to cool buildings in urban areas during heat waves compared to average summer weather. The fundamental issue is that rising temperatures are having a deplorable influence on the well-being of the residents. Due to the heat island effect urban areas are more likely to get affected causing distress in the lifestyle (Gamble et alii 2013, 2008). With rising summer temperatures in cities, conventional cooling systems demand a significant amount of energy to keep buildings cool (IEA, 2018). Therefore, developing nature-based, low cost and low-energy cooling techniques is vital. Nature-based Solutions are defined by Cohen-Shacham et alii (2016, p. 5) as «[…] actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits». By such solutions, our cities and urban landscapes might be transformed into 'urban ecosystems' at the forefront of climate change mitigation through rethinking urban design, architecture, transportation, and planning (EEA, 2010). Sustainable low-energy housing designs are an integral part of developing communities in ways that encourage lower per capita energy use.

Against this background, building façade designs need substantial reconsideration. Vertical gardens are one such possibility (Hoelscher et alii, 2016; Besir and Cuce, 2018; Perini and Pérez, 2021), but they require a lot of mechanical and engineering equipment to operate (Perini and Rosaco, 2013). On the other hand, ground-based vegetation such as trees, are inexpensive, sustainable possibilities that can reap substantial benefits (Morakinyo et alii, 2017; Rahman et alii, 2019; Franceschi et alii, 2022). To further explore the possibilities of the latter option a group of architects, landscape architects, and engineers have collaborated to develop and investigate a basic concept named tree façades. The research project on tree façades as a climatically effective, innovative form of building greening – funded by the German Environmental Foundation DBU – aims at incorporating trees into buildings, especially façades, to improve the thermal comfort in and around the building and to investigate the aesthetic and spatial possibilities that come with the integration of trees into building envelopes.

Due to their large leaf mass and the spatial depth of the canopy, trees growing close to façades could provide microclimatic effects that go far beyond the usual two-dimensional façade greening techniques: local temperature reductions of up to 3.5 °C using trees versus 1.3 °C using façade greening (Pfoser et alii, 2013) and temperature decreases of 9 °C on the façade (Berry, Livesley and Aye, 2013) are possible. Various studies have shown that a tree near a building can offer a variety of comforting microclimate advantages. Most European temperate climates including Germany contain predomi-

Fig. 1 | Half-crown tree at TUM Campus Munich (credit: F. Ludwig).

Fig. 2 | Half-crown tree at Jägerstr. 2-6 Munich (credit: Mahtab Baghaiepoor).

nantly deciduous trees. In the summer they provide shade and let the light through during the winter when all the leaves have fallen. A medium-sized deciduous tree with leaves will reduce irradiance by 80% and one without leaves by 40% (Heisler, 1986). Trees can cool the building surfaces or façades and thereby lessen the energy load for cooling (Akbari, 2002; Pitha et alii, 2018). The heat exchange between buildings and their surroundings is lowered when tree shade reduces the glare of light diffused from the sky. This has a significant impact on people's comfort, reducing heat stress (Abdel-Aziz, Al Shboul and Al-Kurdi, 2105). Trees contribute significantly to the radiative exchange process of ground and wall with considerable reductions in surface and air temperatures. As a result, tree shading is critical in lowering the ambient and surface temperatures of any artificial surface in urban built-up areas, which will indirectly reduce building energy usage (Akbari, 2002; Abdel-Aziz, Al Shboul and Al-Kurdi, 2015).

Apart from the microclimatic benefits of integrating trees into the building façades, trees generate interesting atmospheres within a spatial layer surrounding the building itself. One can imagine living among the trees experiencing the crown with branches and leaves, trunk and bark along with seasonal changes of the whole organism. Aesthetically, trees break the regularity of the building façade and could be separators, avenues at balcony level, privacy providers and many more. Tree façades create a new dimension for designers to explore and generate various temporal atmospheres and even ecosystems in the building envelope (Canepa et alii, 2022). The present research project aims to develop construction principles for the integration of trees in façades and to explore the spatial design possibilities in typological studies. This is done in the context of a concrete case study in Bamberg, Germany. Before the methods 'research by design' and 'research through drawing' as well as the results are presented, the following will explain the approach, define it and distinguish it from other forms of green façades.

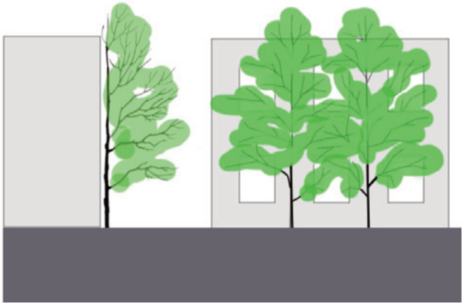
Definition of tree façade | In actual city planning trees are normally planted at a certain distance to buildings to give the tree enough space to develop both crown and roots but also to protect the building façade in case of storm events. Concerns regarding damages to the building foundation or underground infrastructure through roots are also common (Overbeke, 2008; Fernandes et alii, 2019). As a result, seeing or planning trees and buildings closely together is uncommon. However, a substantial amount of very tight growing, mostly private but also some public trees can be observed in the urban context, as shown in Figures 1 and 2 for examples in Munich.

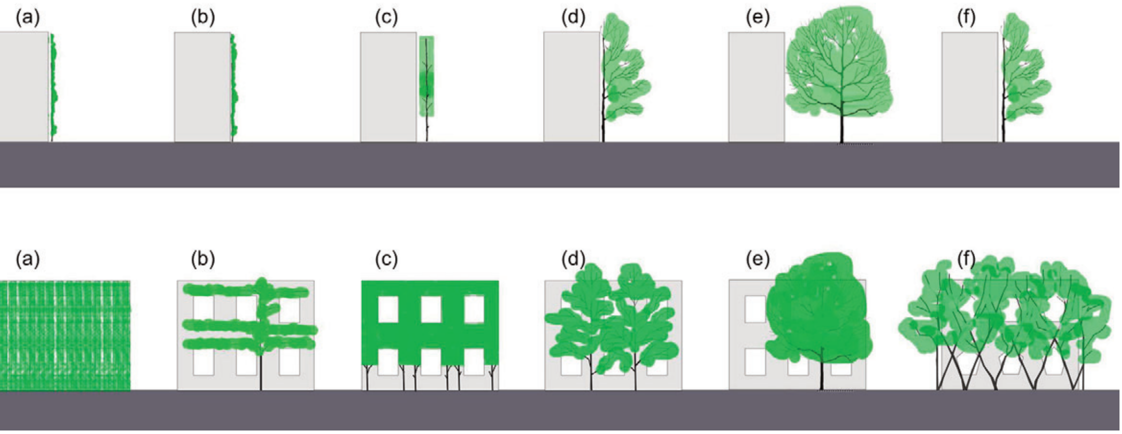
If a tree is growing directly in front of the façade, its normal reaction is to minimize branch and crown development towards the façade and maximize it towards space and light. By intentionally planting trees close to a building and speeding up the natural growth pattern by pruning, it leads to the following definition of a tree façade: A tree façade consists of expansive, large-crowned trees that are planted so close to a building that the tree crown visually becomes part of the building from the outside, while the user of the building can experience the crown space directly from the inside

Fig. 3 | Schematic section (left) and front view (right) of a tree façade (credit: L. Höpfl).

Fig. 4 | Section and elevation of (a) ground-based façade greening with climbers, (b) espalier tree, (c) hedge façade, (d) tree façade (e) tree in front of a building, (f) façade of inosculated trees (credit: L. Höpfl).

Fig. 5 | Hedge façade at Gites Ruraux des Jupilles (credit: C. Guillaume, Gites les Tropes).





or the balcony. Planting the tree close to the façade, accompanied by maintenance pruning measures, leads to the formation of a 'half-crown' (Fig. 3).

To illustrate the difference between a tree façade following this definition and other ground-based façade greening systems the various approaches are compared in Figure 4 in section and elevation. The first category (a) consists of climbers growing on support structures (e.g. trellises, wire ropes) that are mounted at a certain distance from the façade. Depending on the arrangement of the support structures and the selected species this kind of façade greening can have various climatic effects on the building mostly through shading (Pfoser et alii, 2013). Espalier trees (b) are trees that are attached to a trellis structure and shaped into the desired growth form by means of pruning and bending the branches. The canopy has a shallow depth, comparable to the climbers of the category (a). The espalier form aims to use the heat storage capacity mainly of south-facing walls to increase the yield of the fruit tree varieties that are frequently used. A cooling effect is not to be expected very high with the espalier tree, due to the mostly low coverage of the façade. A hedge façade (c) planted directly in front of the façade consists of several trees at close distance to each other, whose canopies are kept in a certain, often architecturally predetermined shape by means of pruning. In this way, windows can be deliberately kept clear to allow the user an unrestricted view of the outside. In contrast to the espalier tree, the hedge façade has a spatial depth of at least one meter. Depending on the canopy volume, hedge façades can have a climatic effect on the building.

On the other hand, a possible limitation of a hedge façade is a relatively high demand for pruning and maintenance efforts, to keep it in the desired form, and a limitation of vertical expansion due to a limited number of high-growing suitable hedge species. A well-known example is the hedge façade of the project Gites Ruraux des Jupilles, designed by the Architect Edouard Francois (Fig. 5). The tree façade (d) systematically stands between (c) and a freely growing tree in front of a building (e), with a large enough distance to the building for the crown to develop fully. For freely growing trees, pruning measures are usually not planned, unless it is a topiary tree or as a safety measure in old age. Although such free-standing trees growing in front of a building develop a large crown volume, the potential climatic effect is limited to parts of the façade only. As a result, cooling effects through shading and transpiration are only possible to a limited extent.

In a direct comparison of all mentioned building greening solutions (Tab. 1), on the one hand, the high design and climatic potentials of tree façades become clear, on the other hand, the complexity of tree façades regarding planning and maintenance is obvious. To exploit the potential and find adequate answers for the challenges is the motivation of the research project at hand.

Methodology | The starting point of this research about tree façades was a request for a tree-integrating architecture in a currently planned social housing project in Bam-

	Planning complexity	Possible variability in design	Potential climatic effects	Effort & Maintenance
Climbing plants (a)	medium - high	medium	medium	medium
Espalier tree (b)	medium	low	low	high
Hedge façade (c)	high	high	high	(very) high
Tree façade (d)	medium - high	high	(very) high	(medium) high
Tree in front of a building (e)	low	low	medium	low

Tab. 1 | First comparison of ground-based building greening solutions to illustrate the potential benefits and challenges of tree façades (credit: L. Höpfl and F. Ludwig).

berg, Germany (Hereinafter referred to as the Bamberg project). A multidisciplinary team of architects, landscape architects and civil engineers came together and found an already well-advanced planning stage of building and site development. Within the framework of the Bamberg project's specifications, possibilities for tree façades were elaborated. Problem identification, common language finding and various design approaches are achieved using drawing as well as graphical analysis (Well and Ludwig, 2020) as tools. In this well-established method called Research by Drawing the building-tree interfaces are understood by drawing, discussing, revising, and comparing, to drive the development process. Various scenarios can be designed and refined in response to the suggestions and knowledge of the interdisciplinary research participants (Bobbink and Loen, 2020; Mäkelä, Nimkulrat and Heikkinen, 2014).

In the case of Bamberg, elements of the Research by Design were applied using «[…] designs to research spatial solutions for a certain area, accommodating a design process, consisting of a pre-design phase, a design phase and a post-design phase, herewith providing a philosophical and normative basis for the design process, allowing to investigate the qualities and problems of location and test its (spatial) potentials, meanwhile creating the freedom to move with the proposals in uncharted territory, and producing new insights and knowledge interesting and useful for a wide audience» (Roggema, 2017, p. 15; Well and Ludwig, 2021).

After coming to specific insights and solutions for the Bamberg project, structural and typological aspects were elaborated using abstraction to transfer into other architectural settings. A deep literature review, especially regarding site conditions at façades, possible tree species, maintenance practices, and also tree moving and static aspects in windy and stormy conditions, was conducted, starting with the Bamberg project and then transferring it to general guidelines. In addition, finite element simulations using geometric nonlinear analysis were carried out to investigate the movement of trees in the wind and any critical stresses that may occur at joints. Since a detailed presentation of this method and the results would go beyond the scope of this article, which focuses on the qualitative aspects of the research, the results section only briefly discusses the most important findings to be able to assess the developed variants in this regard.

Results | Based on the Bamberg Project, basic reflections, critical factors and conceptual considerations arose. It turned out, that understanding tree behaviour and tree static is a key factor in designing tree façades. For Bamberg, three variants (Variant 1-3) were developed from a structural point of view and abstracted for transferring into other contexts (see structural variant results). Another important outcome is a new understanding of the spatial effect of living in the tree crown and the possible atmospheric experiences of a growing and seasonal changing organism. This was particularly developed within the second variant, which uses access balconies for temporary support of the tree façade and is therefore called Laubengang-Typology[1]. As a third result, an approach to aesthetical qualities shows the potential of using tree façades as a way to tie nature experience and human wellbeing together, not only by improving microclimatic effects provided by the tree but also by generating multiple sensual stimuli (see aesthetical results).

Elaborated structural solutions | The three variants presented in this section are motivated by the distinct consideration of the tree in its development from a young tree to a mature tree, as well as its respective wind behaviour. Different flexibility or stiffness gradients exist in the trunk and branches depending on the stage (Fig. 6), resulting in varying degrees of movement behaviour based on wind strength. As a result, the tree and building are vulnerable to harm at various periods and points: 1) Due to insufficiently attached roots (at planting or due to poor root development), the tree may tip over from or towards the building, leading to removal; 2) Shoots, branches, and twigs can strike the façade and break off.

From here, two ways to establish a tree façade were defined: either secure and support the tree temporarily/permanently or integrate the tree's movement into the building design. Also, the process of growing needs to be integrated into the architecture, which leads to interesting changes throughout the development. For the Bamberg project, the following three exemplary variants were developed, typical situations were taken up and possible interfaces were considered and are shown in an overview in Figure 7:

– Variant 1 is a scaffold pole that is permanently but elastically fixed to the building; the leading shoot of the tree is fixed to the scaffold pole during planting and continu-

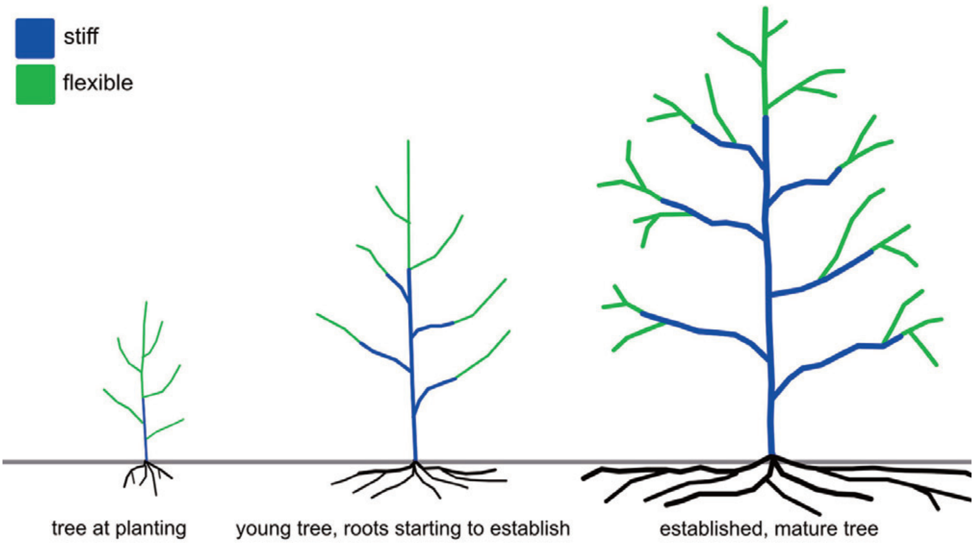


Fig. 6 | Schematic representation of the tree flexibility-stiffness in 3 age stages (credit: L. Höpfl).

ously pulled around the pole as it grows; the aim is to achieve a permanent intergrowth of the pole and the tree;
– Variant 2 uses structural elements such as loggias, balconies or arcades to integrate a structural element that embraces the tree and fixes it temporarily and only in tension (e.g. with ropes) until sufficient rigidity of the tree is achieved;
– Variant 3 leaves the tree with a little more distance in front of the building so that the tree can move relatively freely in the wind; here, temporary support systems are only envisaged during the establishment phase.

Variant 1 | This variant places the trees of the tree façade at a very small distance (less than one meter) from the building. However, the tree should not be placed closer than half its root ball size when planted, so that the tree is not weakened by additional highly intrusive pruning measures in the root area. The proximity to the building means that the root space to one side is severely restricted and the roots can only spread away from the building. To assist the young tree in its anchoring and growing process and to protect the older, more stable tree with a flexible shoot tip from buckling in high winds, a pole is proposed to reduce leverage, prevent the tree from tipping over, and stabilize the tip (Fig. 8). In this variant, the scaffold pole is designed to be permanent. The elastic shoot tip is regularly wrapped around the scaffold pole so that the tree and the pole grow into a single unit over time as the tree grows in thickness (Figure 9; compare the research on Baubotanik structures[2]; Ludwig and Storz, 2005; Ludwig, 2008, 2021; Ludwig, Schönle, and Vees, 2016).

As the tree grows in height, an expansion of the circumference is essential to ensure the tree's supply and stability. Division processes in the cambium, the tissue layer under the bark, lead to a ring-shaped enlargement of the shoot. If there is an obstacle in the zone of thickness growth, such as the scaffold pole, in this case, it is enclosed and inosculated over time in such a way that the pole is only partially visible from the outside, or not at all. The shoot-scaffold pole connection is elastically supported via a tension-compression spring at special connection points on the building, whereby the coupling of the static system building, and the flexible system scaffold pole-tree is a challenge that should be considered early in the planning process (Fig. 10). Detailed finite element modelling of the inosculated pole and its direct connections to the building showed that there is a risk of stress peaks at the end when the tree outgrows the pole as well as at the support points. This can be avoided by a gradual load transfer from the tree into the support, either by elastic connection details between the pole and building or a gradual decrease in stiffness of the pole towards the crown of the tree.

Maintenance of variant 1 includes regular pruning of branches that may grow towards the façade as well as continuous guidance of the shoot tip around the scaffold pole. Due to the small distance from the façade and overhanging branches of the tree, the accessibility of the trunk is limited. If the building has a parapet, specially trained gardeners or tree climbers could rappel down from there and operate directly between the building and the tree façade. This would allow for very precise maintenance. Alternatively, maintenance can be carried out from the ground using ladders or a lifting platform, whereby the accessibility of the ground must be guaranteed without harming the root space of the tree façade. In Variant 1, the building and the tree merge almost completely through the physical connection and spatial proximity. This creates not only a constructive but also a visual unit, which leads to new spatial qualities in and around the building.

Variant 2 | This variant integrates the tree into an existing component of the building like a loggia, a balcony or an arcade and fixes it temporarily. This places the tree at a defined distance in front of the building, which on the one hand restricts the root space less and on the other reduces the risk of damage to the tree or the façade in windy conditions. Depending on the stage of development (Fig. 11), the tree is tied temporarily in suspension to special devices integrated into the building component, for example using elastic tree ties or coconut ropes. The fixtures can be recessed or cantilevered railings or guides (Fig. 12). Once the tree is established, the temporary ties are removed.

Finite element modelling has shown that stress peaks can occur in the trunk during strong gusts if it is directly connected to a fixed support. The additional stiff support leads to the highest bending moments at the upper part of the trunk rather than at the root. This can lead to the so-called 'karate effect' where the trunk breaks above the support in the case of high dynamic wind loads (Detter, 2019). To prevent the tree from breaking, the trunk should instead be held elastically, e.g. with ropes and elas-

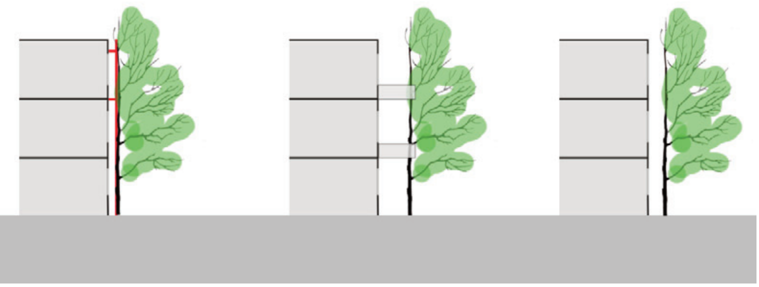


Fig. 7 | Connection with the ingrowing pole – Variant 1; Temporary connection – Variant 2; Tree standing freely in front of façade – Variant 3 (credit: L. Höpfl).

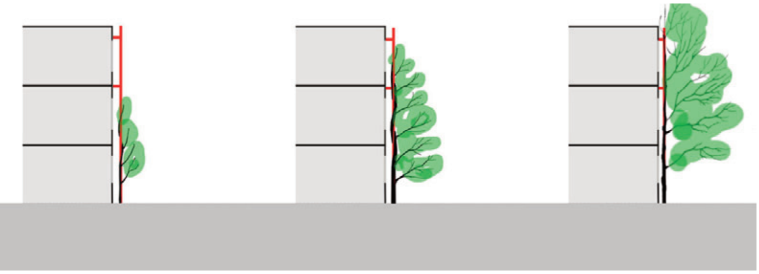


Fig. 8 | Development over time of Variant 1 (credit: L. Höpfl).

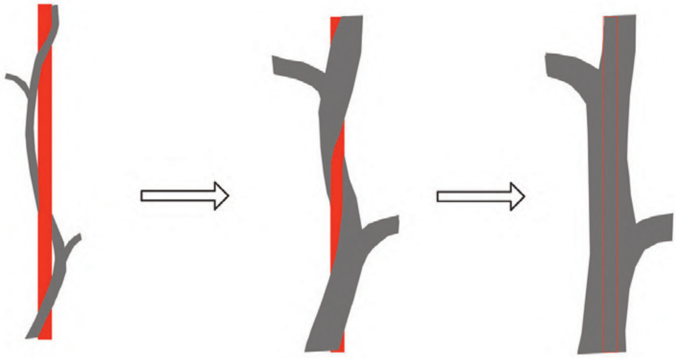


Fig. 9 | Inosculation process of the shoot tip and the pole (credit: L. Höpfl).

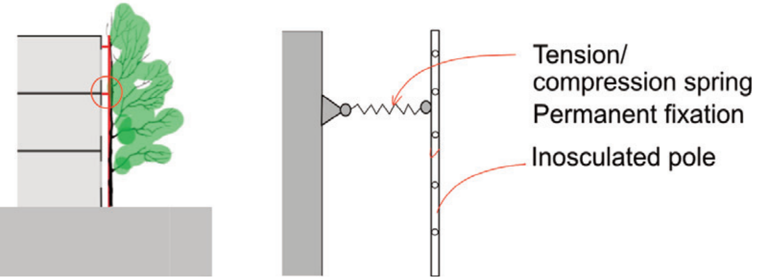


Fig. 10 | Schematic structural detail of Variant 1 (credit: L. Höpfl and J. Lienhard).

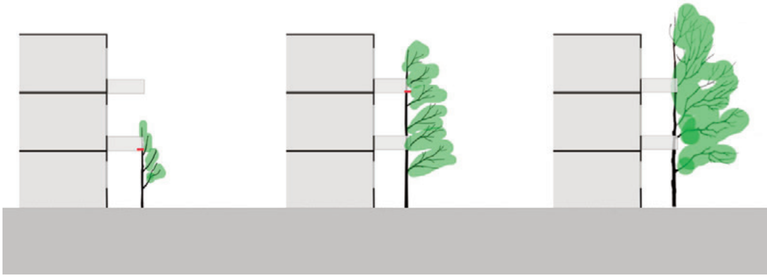


Fig. 11 | Development over time of Variant 2 (credit: L. Höpfl).

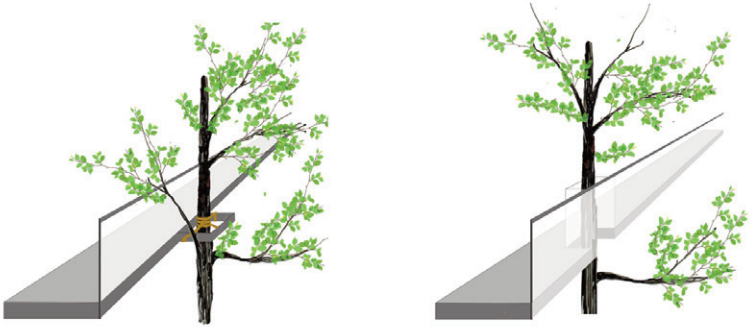


Fig. 12 | Possible tree and building joinery (credit: L. Höpfl).

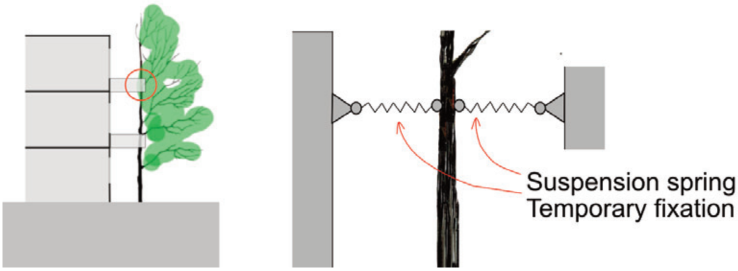


Fig. 13 | Static of Variant 2 (credit: credit: L. Höpfl and J. Lienhard).

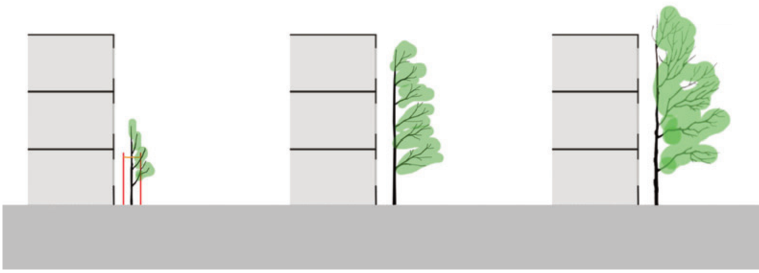


Fig. 14 | Development over time of Variant 3 (credit: L. Höpfl).

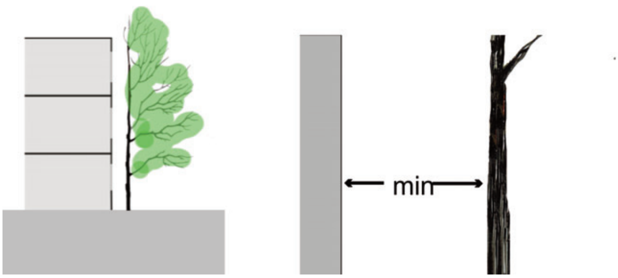


Fig. 15 | Static detail of Variant 3 (credit: L. Höpfl and J. Lienhard).

Comparison	Way of fixing	Complexity of planning	Maintenance	Effort & cost	Possible distance to façades
Var 1 **Permanent fixing with inosculated pole**	permanent, elastic, Tension-compression anchoring	high	demanding	high	Very low
Var 2 **Temporary fixing**	temporary, Tension- anchoring	medium	medium	medium	Depending on the building structure
Var 3 **Tree with distance to the building**	temporary while establishment phase (planting)	medium	medium	medium	low

Tab. 2 | Comparison of structural variants (credit: L. Höpfl and F. Ludwig).

tomeric dampers (Fig. 13). The maintenance of this variant is limited to the pruning of branches growing towards the façade and the control, adjustment and removal of temporary tethers. If balconies or pergolas are provided on the building anyway, this is a simple and relatively inexpensive way to establish the tree façade. Spatially, this variant can appear more distant, depending on the size and design of the architectural component the tree is integrated into. However, skilful planting at corner positions can create a tree façade privacy screen, which in turn has a spatially and climatically interesting effect (see special application results).

Variant 3 | This variant moves the tree away from the façade at a greater distance (more than one meter) and ties it independently of the building and only temporarily, for example, with a tree stake, tripod or underfloor system after planting until the roots are sufficiently anchored in the ground to stabilize the tree (Fig. 14). The distance kept from the façade allows the roots – at least partly – to develop in both directions, which has a positive effect on the development of the entire tree. The swinging of the branches in the wind and a possible touching of the façade is accepted here.

By using the finite element model, deformations of a free-standing half-crown tree under strong winds can be determined. The simulated trunk and branch movements provide information about the necessary distance of the tree from the façade so that both the façade and the tree are not damaged in a storm (Fig. 15). The results vary depending on the chosen species and the age of the tree. The maintenance of Variant 3 consists only of the removal of the temporary fixation in the ground after the establishment of the tree façade and regular pruning of the branches growing towards the façade. Accessibility depends on local conditions. Variant 3 has no direct interfaces with the building and is, therefore, more cost-effective in terms of establishment and maintenance, but here possible movements of the tree towards the façade must be planned for in the event of strong winds. Depending on the building type and available resources, the structural variants of the tree façade presented here are differently suitable for integration into the architectural concept: Table 2 shows a comparison.

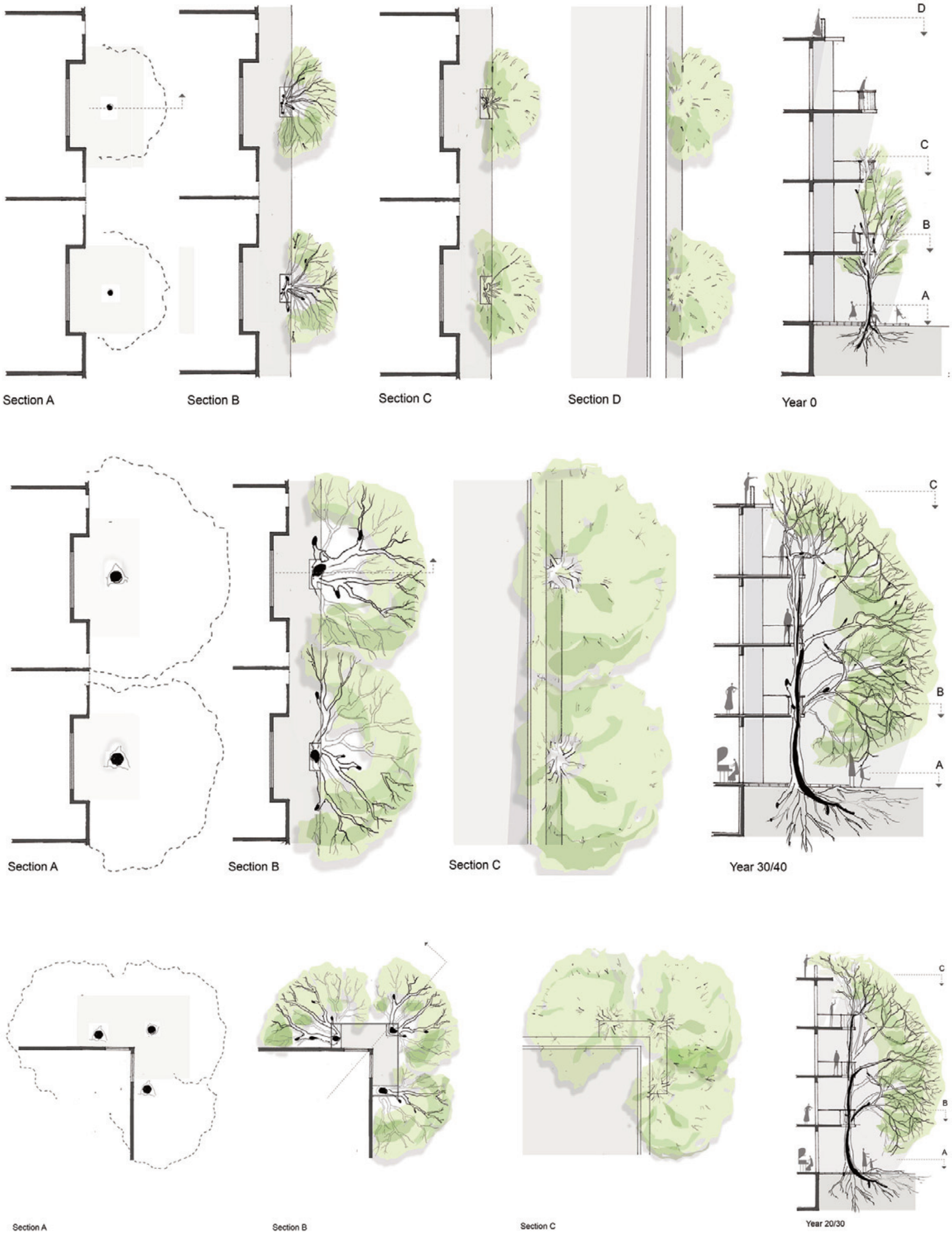
Elaborated spatial typologies | Applications of tree façades and their spatial features were explored by elaborating three typologies of the structural Variant 2 described above by placing trees in front of, around, and between balconies or corridors, considering the following aspects: 1) Time – while the overall shape and appearance of the building is completed when first users move in, the tree façade is still in the early stages of growth at the time of planting; the process of developing an effective height and crown volume takes 20-40 years; spatial experiences are therefore under constant change; thinking in such time dimensions influences also the life cycles and needs of the inhabitants as well as the social components of the architecture; 2) Light – figuring out the balance between enough light for and views out of the spaces over the summer while reducing temperatures in the exterior and interior spaces; design factors here include the distance of the trees from the building, the tree species with its canopy structure and foliage density, and the density of the tree façade planting itself.

Laubengang typology – Cantilevered corridors allow the trees to be fixed, at the same time it serves as a platform for maintenance. While the shading of the façade is ensured by the cantilevered corridors even at the beginning of planting, the previously open corridor itself is increasingly screened by the trunks and branches of the trees in the further growth process (Figg. 16-18). The façade also changes from the outside perspective with the growth of the trees and the foliage in summer.

Green Niche typology – A tree façade planted around a corner balcony allows life inside the trees like in a green, sheltered cocoon. Temporarily attached to the balcony, the trees develop an internal space on the balcony and enhance an introverted feeling (Fig. 19).

Screen typology – Trees between the balconies allow a natural separation between nearby balconies and life in the tree while the balcony allows an open view of the surrounding. Depending on the distance, the crown close to the balcony can be experienced from the inside whereas the neighbouring crown will be experienced from the outside.

Elaborated spatial and aesthetic results | The spatial component and the effect of the tree façade depends on the distance and arrangement of the trees in front of the building, but equally on the age of the trees and the height from which the tree crown is experienced. The experience of living in a tree changes in the course of growth, but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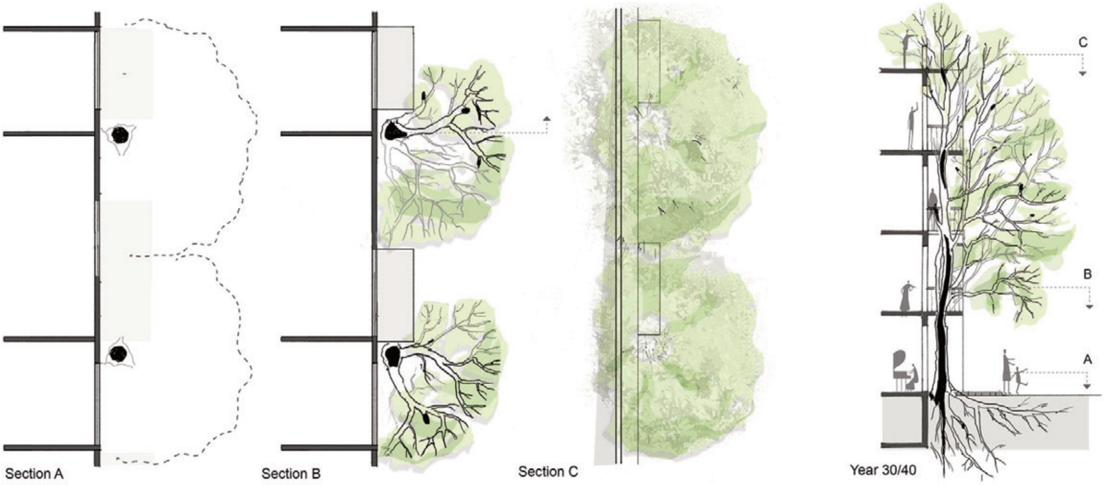

Fig. 19 | Mature trees acting as a separator between the balconies, approx. 20-30 years (credit: D. Pilla and F. Köhl).

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Fig. 16 | Trees in front of the house: Laubengang typology at the time of planting (credit: D. Pilla and F. Köhl).

Fig. 17 | Mature trees in front of the corridor: Laubengang typology (credit: D. Pilla and F. Köhl).

Fig. 18 | Mature trees on the corner balcony, approx. 20-30 years (credit: D. Pilla and F. Florian Köhl).

also within the seasons: while the freshly planted tree can initially only be experienced in the lower storeys, the crown as a whole is still small and the spatial depth rather shallow, over the years it develops into a large, shady tree that creates its own crown space on each storey through the depth of its branches. Depending on the season, the trunks, branch structures and foliage create a carpet of plays of light and shade on the façade, balconies or arcades, extending into the living spaces. The views also change with the season, the age of the tree and the experienced height of the treetop: in winter, light enters the living spaces, and the view opens, guided by branches into the surroundings, while in summer the foliage allows more partial views and inspires an introverted experience of the closer treetop.

The immediacy of the tree allows the user to experience its characteristics visually, but also haptically: the texture of trunk, bark and branches, the settling of mosses, the hibernation of buds in the cold season, only to sprout in spring and be blown away as colourful leaves in the autumn wind. Rain and wind also play a key role in the experience of spatial-sensory qualities. Through the slight or strong movement of branches and leaves, the delayed dripping of water after a summer rain or the snow on the branches in winter, weather and season suddenly become immediately visible and are enriched by new, not everyday observations, such as sounds of flapping branches and

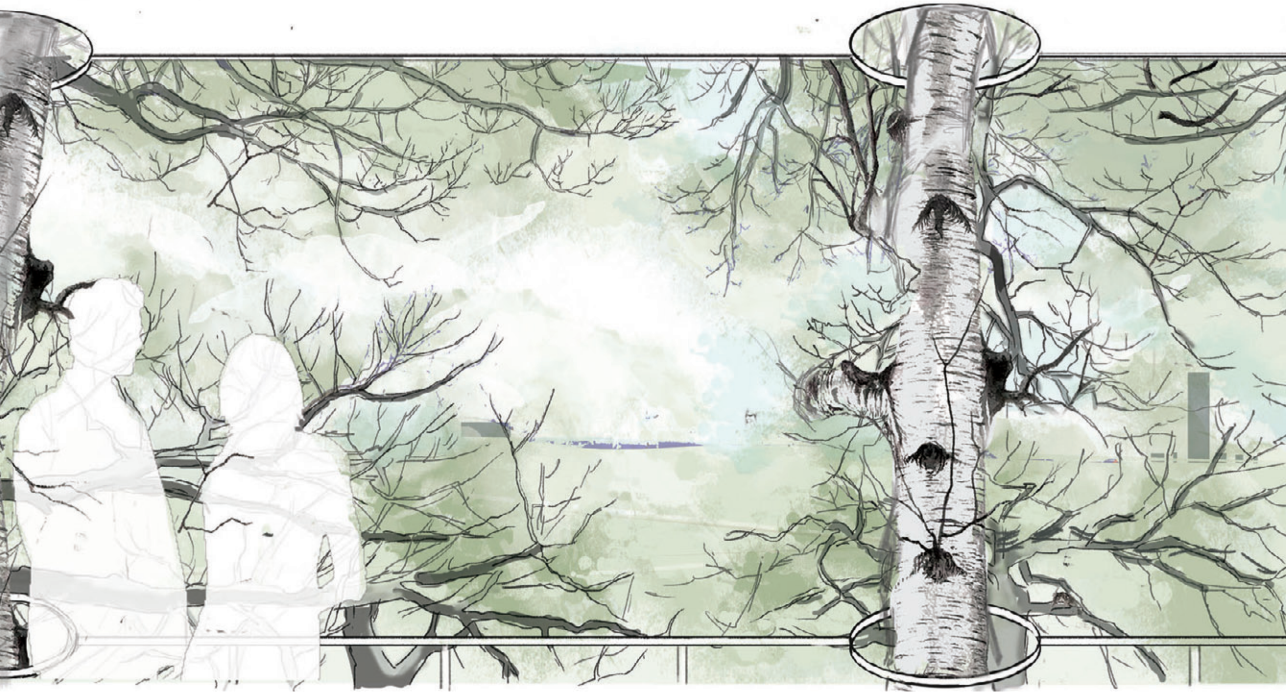

Fig. 22 | Tree façade framing the view (credit: D. Pilla and F. Köhl).

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Fig. 20 | Tree façade perceived from interiors (credit: D. Pilla and F. Köhl).

Fig. 21 | Tree as a substantial element of the balcony (credit: D. Pilla and F. Köhl).

rustling leaves and smells of fresh leafy greens, bark or rain. This and the possibility to observe birds and insects on the balcony or from the living room brings a new kind of experience of nature into the user's immediate living environment. These qualities have been elaborated by a series of perspective drawings (Figg. 20-22).

Discussion and Conclusion | A tree façade is a project dealing with various interfaces. From the Bamberg project and the resulting design research, the following conclusions can be drawn for a tree façade approach. First, there is a necessity in overcoming obstacles in the multidisciplinary cooperation with Architects, Landscape Architects, Structural Engineers, Gardeners, and stakeholders involved in the planning process. Therefore it is important to understand the different approaches and tasks of each discipline, to develop a new, integrated language, and implement new methods for decision making. It turned out that by using drawing and designing as a method, content and conflicts can be identified very quickly. Besides, it was shown that for integrating time and process in the planning practice drawing is a comparative tool which is easy to understand and to use for all involved actors. Still, it remains a challenging task for all planners to fully imagine various spatial and atmospheric experiences, especially considering constant change, as most disciplines are trained to think in non-changing results. Also, cross-disciplinary consequences of using tree façades, like an adaption of floorplans or different designs of foundations for buildings, bear enormous potential that is not revealed yet in the building practice, and trees are often treated like an ‘add-on’. Coming together in an early planning stage is therefore crucial (Well and Ludwig, 2021).

The results of the paper are limited to the insight gained and abstracted from the Bamberg project. As theoretical research, it now needs practical implementation and monitoring both in the Bamberg case and elsewhere. Assembly of data and regular documentation over time must demonstrate the microclimatic and other beneficial effects of building with trees. As Bamberg is a social housing project the impact on the residents and the influence on the social interaction should be stated and investigated over time. Also, it is very likely that a natural feeling of distance and the positive effect of looking into green leaves reduces stress (Huang et alii, 2020) and improves social performance (Kuo and Sullivan, 2001).

In dense urban areas tree façades present a completely new way of merging building greenery and urban green, stacking benefits of cooling and shading, and other ecosystem services, but also hold the option to develop a whole new streetscape. This allows for example to reorganize pedestrian, cycle and motorized zones, having trees close to buildings and more open space towards the middle of the street. As tree facades hold potential for various benefits beyond the building (e.g. shading and cooling the street), the cost for investing and maintenance remains with the developer or owner. This is also an issue for future discussions and invites to develop progressive and interwoven responsibilities between the municipality and stakeholders.

The study at hand can be seen as the first attempt in those directions. If proven, tree façades could serve as a model for future architects, planners, and engineers in a multidisciplinary forum for designing solutions for adaptation to climate change on the urban scale, but also to elaborate high-quality building environments with nature integrated into the architecture. The study, however, was limited to Northern Europe, specifically Germany. This may limit the design’s applicability in other regions of the world but does not rule out the possibility of tree façades in other climates.

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Notes

1) Laubengang Typology in this case means arcades build from trees or in terms of horticulture: an arbour walk.

2) The term Baubotanik describes a form of architecture in which structures are created through

the interaction of technical joining and plant growth by manipulating the growth of trees or their parts, joining them with each other and connecting them with non-living components in such a way that they merge into a botanical-technical entity.

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