FINAL REPORT

CHAIR OF LANDSCAPE CONSTRUCTION, TU BERLIN

Fachgebiet Landschaftsbau-Objektbau, ILAUP

Landscape architecture and the time factor:

Construction research on the contextual change of built landscape elements and the development of optimisation strategies

Final report on the DFG-Projekt 242199665, Sepember 2018


Year 16


Year 7


Year 10


Year 17


unknown


Year 0/2


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Year 6


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Year 3

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LANDSCAPE ARCHITECTURE AND THE TIME FACTOR: Construction research on the contextual change of built landscape elements and the development of optimisation strategies.

GENERAL INFORMATION

1.1 DFG REFERENCE NUMBER

242199665 *(https://gepris.dfg.de/gepris/projekt/242199665)*

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1.4 FUNDING PERIOD

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2 LIST OF THE MOST IMPORTANT **PUBLICATIONS**

The project has led to five peer reviewed papers with presentations at international European Council of Landscape Architecture Schools (ECLAS) conferences in Switzerland, Belgium and England together with chapter for a forthcoming ECLAS handbook on teaching methods in landscape architecture. A sixth manuscript is currently being finalised together with Prof. Dr. Norbert Kühn (Chair of planting techniques and design, TU Berlin) concerning the strategic implementation of 'enhanced spontaneous vegetation' in built landscapes (see list below). A journal article was also published in Anthos by the Swiss Federation of Landscape Architects (BSLA) and a recent Blog and E-Newsletter focussing on the results of the research project has been widely posted to over 7,000 readers by the Landscape Architecture Foundation (LAF) in the USA.

2.1 Published peer-reviewed articles

COLWILL, Simon (2016): *Time, Design and Construction: Learning from Change to Built Landscapes Over Time.* In Bridging the Gap. ECLAS Conference 2016, Rapperswil, Switzerland. Conference proceedings. ISSN 1662-5684, ISBN 978-3-9523972-9-9.
URL: https://www.ilf.hsr.ch/ECLAS-2016.14490.0.html
Including conference lecture

COLWILL, Simon (2017): *Time, Patination and Decay.* In Creation/Reaction. ECLAS Conference 2017, University of Greenwich, London UK. Conference proceedings, pp. 293-314. ISBN: 978-0-9935909-6-2
URL: https://eclas2017.files.wordpress.com/2017/08/eclas-2017-book-proceedings.pdf
Including conference lecture

COLWILL, Simon (2017): *Climate and Decay: The impact of the urban climate on built landscape.* ECLAS Conference 2017, University of Greenwich, London UK. Conference proceedings, pp. 315-332. URL: https://eclas2017.files.wordpress.com/2017/08/eclas-2017-book-proceedings.pdf
Including conference lecture

2.2 Peer-reviewed articles not yet published

COLWILL, Simon (2018): *Use and Abuse: Reading the Patina of User Actions in Public Space.* ECLAS Conference 2018, University College Ghent, Belgium. Conference proceedings (in press)
Including conference lecture

COLWILL, Simon (2018): *The Root of the Problem: Addressing the Conflicts between Spontaneous Vegetation and Built Landscape.* ECLAS Conference 2018, University College Ghent, Belgium. Conference proceedings (in press)
Including conference lecture

COLWILL, Simon: T*eaching Landscape Construction: On-site learning.* In: Routledge Handbook of Teaching Landscape (2018). [S.l.]: Routledge.
Elke Mertens (Editor), Nigul Karadeniz (Editor), Karsten Jorgensen (Editor), Richard Stiles (Editor), ISBN-13: 978-0815380528, ISBN-10: 0815380526 (in press)
Publication planned: autumn 2018

2.3 Peer-reviewed articles in preparation

KÜHN, Norbert; LOIDL-REISCH, Cordula; COLWILL, Simon: *The strategic implementation of 'enhanced spontaneous vegetation' at points of high vulnerability in the built landscape.*

2.4 Other publications

Journal:
COLWILL, Simon (2016): *'Von Alterungsprozessen lernen'*, (German, French) In: Anthos. Nr. 3-16, S 31-33. Zürich: Bund Schweizer Landschaftsarchitekten und Landschaftsarchitektinnen.

Blog:
COLWILL, Simon (2018): '*Time and Landscape Performance'.* Newsblog / E-Newsletter with over 7000 readers. Landscape Architecture Foundation, USA. Posted 14th August, 2018 as Newsblog under 'Design Education' and Landscape Performance Research' and as E-Newsletter. Available at: lafoundation.org/news-events/blog/2018/08/14/time-and-landscape-performance

3 PROJECT-SPECIFIC **WORKSHOPS SYMPOSIUMS AND LECTURES**

3.1 Project specific workshops / symposiums

Project-specific multidisciplinary workshops and symposiums broadened the focus of this research project, allowing for the exchange of knowledge and providing feedback from the research project to a wide audience such as researchers, public authorities, practitioners, clients and landscape contractors. The results were fed back into the research activities.

The first international workshop took place in 2016. Initial results of the research project were presented and discussed together with presentations of experts from related fields of study. The second day focussed on interdisciplinary discussion of the main topics of the research project and the development of optimisation strategies.

'Reading Patina 1.0: Learning from the deterioration of built landscapes through time'.
International Symposium und Workshop, 7th to 9th July 2016 (held in English)
DFG research project lectures:
Simon Colwill, TU Berlin
'Reading Patina: Theory and Practice'
'The Reading Patina Database'
'Vandalism!'
Prof. Cordula Loidl-Reisch, TU Berlin
'Built to be Wild'
Guest Lecturers:
Assoc. Prof. Liat Margolis, Toronto University (CA)
Barbara Deutsch, Landscape Architecture Foundation (USA),
Dr. Bettina Wettstein, TU Kaiserslautern (DE),
Keynote lecturer:
Prof. Niall Kirkwood, Harvard Graduate School of Design (USA)

The second workshop took place at the TU Berlin in 2018. Final research results were presented and discussed. Presentations of experts from associated disciplines allowed a broad discussion of the research topic.

'Reading Patina 2.0: Zeit und Veränderung' (time and change).
Symposium/workshop, 5th July 2018 (held in German)
DFG research project lectures:
Simon Colwill, TU Berlin
'Zeit und Veränderung' (time and change)
Guest Lecturers:
Prof. Peter Petschek, Hochschule für Technik Rapperswil (CH)
Dr. -Ing Florian Bellin-Harder, Universität Kassel (DE)
Dr. Noël van Dooren, Van Hall Larenstein Velp (NL)


Year 3


Year 4

3.2 Academic field study workshops

Three student assisted field study workshops were conducted within the framework of the research project focussing on key issues of the research.

'Vandalism' (2014): The workshop dealt with defining and analysing the different types of misuse and vandalism of public space found in Berlin. The results are discussed in the paper:
COLWILL, Simon (2018): *Use and Abuse: Reading the Patina of User Actions in Public Space.* ECLAS Conference 2018, University College Ghent, Belgium. Conference proceedings (in press)

'Weathering, Climate and Decay I' (2015) and **'Weathering, Climate and Decay II' (2016):** with the support of Dr. Marco Otto at the Chair of climatology, TU Berlin, Dr. Björn Kluge and Joachim Buchholz at the Chair of soil protection, TU Berlin. Both workshops focused on assessing the influence of the atmosphere on various built landscape elements made of differing materials by using thermal-imagery and data from a mobile weather station. Measurements were taken in the winter and summer semester. The results were presented at the 'Reading Patina 1.0' conference, July 2016 and discussed in the paper:
COLWILL, Simon (2017): *Climate and Decay: The impact of the urban climate on built landscape.* ECLAS Conference 2017, University of Greenwich, London UK. Conference proceedings, pp. 315-332.

3.3 Academic lectures held

An ALSA Student Lecture (American Society of Landscape Architects) was also held at Harvard University.

Simon Colwill, TU Berlin - **'Time, Design and Decay'**, 5th April 2017

Host: ASLA Students, Harvard Graduate School of Design, Harvard University, Boston, USA

4 FINAL PROGRESS **REPORT**

4.1 Project's initial questions and objectives

The central aim of this research project was to develop monitoring methods to assist landscape architects, clients and contractors in identifying and diagnosing (diagnosis) **weak points and vulnerabilities** in built landscape works, thus avoiding them in new projects (prognosis). The research also focused on developing **optimisation, prevention** and **protection** strategies for the weaknesses identified. The objective is to optimise the quality and durability of built landscape architecture projects in terms of sustainable planning, construction and maintenance processes.

The research project was based on the hypothesis that **it is possible to optimise design, detailing, construction and maintenance techniques by monitoring and evaluating the development of projects at regular intervals after completion.**

The subjects of research were landscape elements, or combinations of these in public or semi-public open spaces, built between 1990 and 2015 in the city of Berlin, Germany. Since reunification, a large number of typologically different projects have been planned and implemented in Berlin. The current, often desolate state of some of these projects reflects on the one hand the financial distress of the city (BMUB 2015: 12, 33, 74) - a

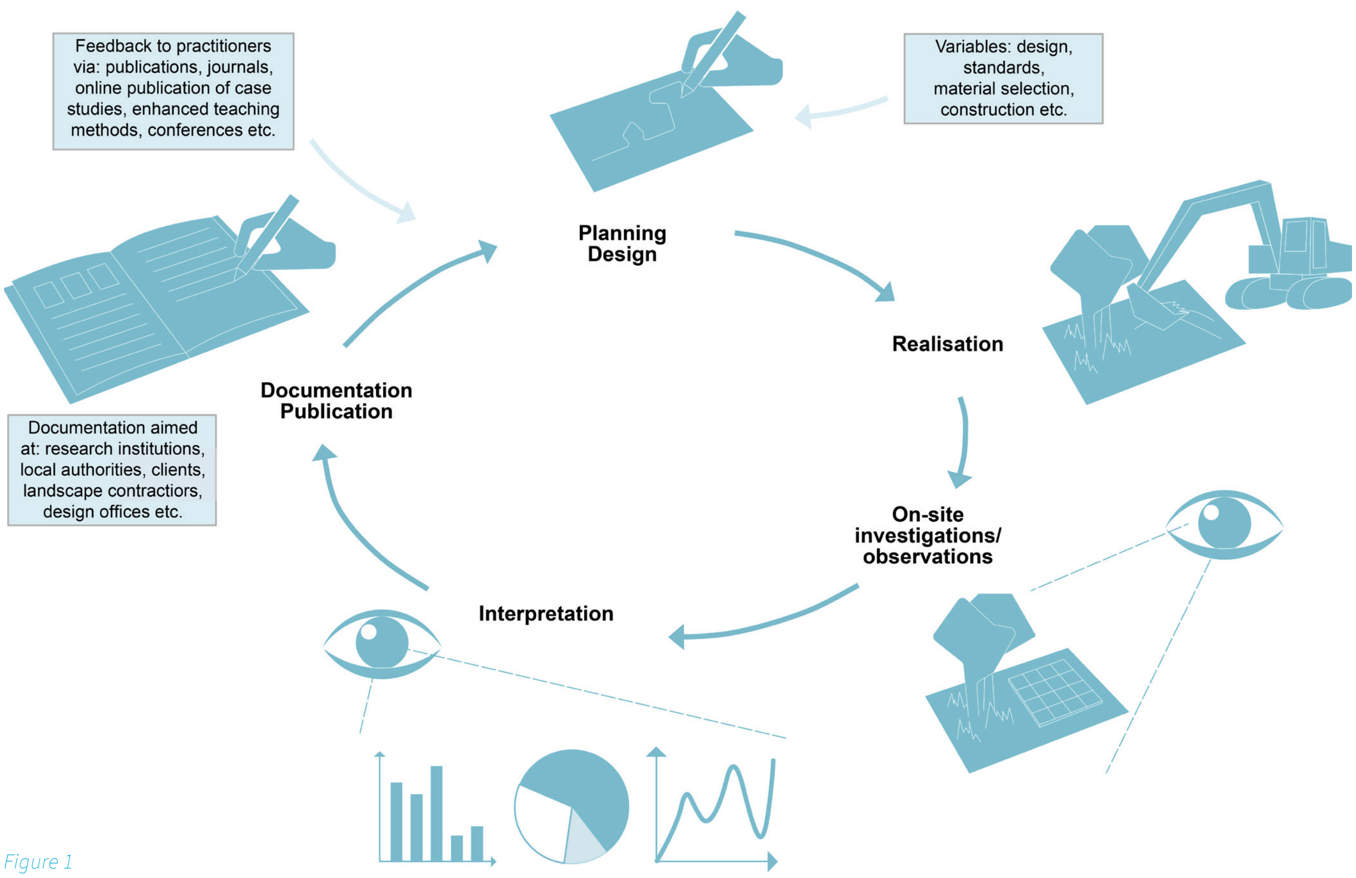


Figure 1

Schematic diagram of the hypothesis

fact that increasingly applies to cities throughout the world - on the other hand a clear lack of knowledge on the time-bound and contextual processes of change (Colwill: 2018c). The required design, material and constructional bandwidth of the objects to be examined was achieved by selecting a large number and variety of open spaces such as city squares, parks, forecourts and promenades by diverse international landscape architects. Award winning projects or those resulting from national or international design competitions were preferred. For the purpose of narrowing down the subject area playgrounds, green roofs, plantings, water features and private open spaces were excluded from this study.

Weak points are areas of a structure that due to the design, construction, particularly exposed location (corners, edges etc.) or particularly high demands (surfaces with ground contact etc.) are of especial vulnerability. Inherent weaknesses are an inevitable and unavoidable factor of all structures resulting from the design of the structure, material properties and wear and tear; for example, mechanical damage to exposed table corners or the natural discolouration of wood (greying) (Colwill 2017b: 294). Inherent weakness can be optimised, but not completely eliminated, through improved design, quality of materials and maintenance. However, weaknesses can also be caused by misjudgements in the planning and execution of the design, low quality materials, poor workmanship and maintenance, and are often the result of budgetary restraints. These weaknesses can be minimised or avoided through increasing awareness of previous failures by monitoring change and providing feedback to the profession– thus avoiding failure repetition (Ibid).

We define built landscape elements as the physical component parts of a landscape construction. These include individual materials and assemblies of materials such as structural elements and site furniture. This research focused on the following classifications of landscape elements:

BUILT LANDSCAPE ELEMENTS

- Decking, platforms and boardwalks
- Drainage elements
- Facades and structures (adjoining surfaces and elements)
- Fences, railings, handrails and barriers
- Irrigation systems
- Paving and edgings (exterior flooring)
- Ramps
- Services and manhole covers
- Site furniture:
    - Benches
    - Bike stands
    - Bollards
    - Lighting elements
    - Signage
    - Waste containers
- Steps
- Tree grates and guards
- Vegetation and planting details
- Walls

During the course of the research new material specific and material unspecific classifications became necessary in order to address the specific characteristics of the weak points identified.

MATERIAL SPECIFIC WEAK POINTS

Material specific weak points result from the specific properties of individual materials and their surface treatments.

MATERIAL UNSPECIFIC WEAK POINTS

These weak points are independent of the specific implemented material or building elements. Problems occur mainly due to susceptibility to malicious damage, graffiti and spontaneous growth in the public realm.

Built landscapes undergo constant dynamic change, for example, due to exposure to environmental forces, the processes of use and misuse, and the intensity and frequency of maintenance and repair (Colwill, 2017a: 315, 316). Landscape elements and materials are therefore subject to a variety of stresses such as:

- Specific mechanical stresses on the elements themselves resulting, for example, from the design, construction methods, choice of materials or constructive building protection.
- Contextual mechanical stresses on built landscape elements influenced by the space in which they are located, for example, the level of exposure, the specific climate, the type and intensity of use and vandalism.

The research project aimed to record, analyse and evaluate these stresses while taking into account the processes of time-bound change.

The research proposal itself was based on findings gained over the preceding years from diverse preliminary investigations in the context of teaching and research at the Technical University Berlin. The extensive collection of approximately 60,000 multi-temporal photographic recordings and on-site investigations taken between 2008 and 2013 from landscape architecture projects in Berlin, formed the basis of the research application. The preliminary research enabled the main focus and methodology of the research proposal to be defined. This led to the development of the following scientific sub-objectives:

- Expand the depth of **knowledge** on interactions between design, building materials, technical implementation, maintenance and time-bound, contextual change processes that occur after completion.

- Develop a **non-destructive method** for the detection and localisation of frequently occurring weak points and vulnerabilities in built landscape architecture in the sense of a low-threshold and non-destructive diagnostic and prognostic tool. Identify the types and frequency of the pathologies found.

- Determine through in-situ **investigation** the possible causes (contextual mechanisms and processes) of specific effects (visible indicators) on built landscape elements over time.

- Establish a **monitoring procedure** for assessing weak points, vulnerabilities and general performance of built landscape elements in public open spaces by documenting and evaluating change. This also involves the creation of a **data collection system** for the development and storage of this time based knowledge.

- Develop a **forecasting instrument**, which aims to optimise future built landscape elements in the planning phase with regard to durability, resilience and maintenance and thus makes a significant and necessary contribution to sustainability.

- **Exchange knowledge** between various stakeholders through interdisciplinary expert interviews and evaluations, symposiums and workshops thus developing a shared knowledge base.

- Develop **optimisation, prevention** and **protection** strategies for dealing with weak points and vulnerabilities in the design, construction and maintenance of landscape architecture projects.

- **Disseminate** the research results to the broadest possible audience through workshops, symposiums, presentations at conferences, teaching and publications

4.2 Project developments

The research method was based on empirical inquiry following the case study methodology involving both qualitative and quantitative evidence (Yin 2014: 109; Colwill: 2018a). Photographic recordings were taken at regular intervals over a 5-8 year period from the time of project completion. Further surveys of older projects allow for a period of up to 25 years to be analysed. Through comparisons between the original state and successive recordings (**pre-post comparison**) process-dependent changes become visible. The multi-temporal images depicting specific weak points and vulnerabilities over time were then chronologically ordered as **sequences** and grouped to form **case studies**. Each of the case studies resulting from the field research represents the development of 'a contemporary phenomenon within its real life context' (Ibid: 13). The principles of construction pathology were used to identify relationships between the 'visual signs and symptoms' (effects) observed and pathological conditions' (causes) (Watt 1999: 1-7, 159-165). This enabled causes to be determined and recommendations for the most appropriate course of action to be made (Ibid). A quantitative analysis of the results revealed frequently occurring points of weakness and vulnerability that need special attention in design, detailing, implementation and maintenance. Comparisons of the rate of change allowed for premature ageing to be determined, and the most significant causes identified.

In order to advance the research results beyond academic audiences and gain first-hand knowledge from active practitioners in the field, **multidisciplinary expert interviews and evaluations** with landscape architects and landscape contractors as well as with researchers took place.

Figure 2 provides an overview of how the research project was structured.

The research project was carried out based on the following clearly defined **work program**. These work phases were not planned as a strictly linear model thus allowing for a sequence of iterations and changes during the research activities.

WORK PHASE 1: THEORY

The first **working phase** of the research program determined the existing state of scientific knowledge through in-depth **multidisciplinary** research in libraries, archives, databases, etc., as well as interviews with experts. Working methods, a procedure for project selection and an evaluation system for landscape building elements were also developed.

WORK PHASE 2: COLLECTION OF SUPPLEMENTARY DATA

The second phase focused on the implementation of the remaining site surveys as a basis for the subsequent analysis and evaluation. This data mainly consisted of photographic images at three zoom factors- **context images** (represent the total site as well as contextual and spatial interrelationships), **object images** (show the individual landscape elements as well as the transitions to adjacent surfaces and objects), and **detail images** (provide detailed information on the construction, surfaces and

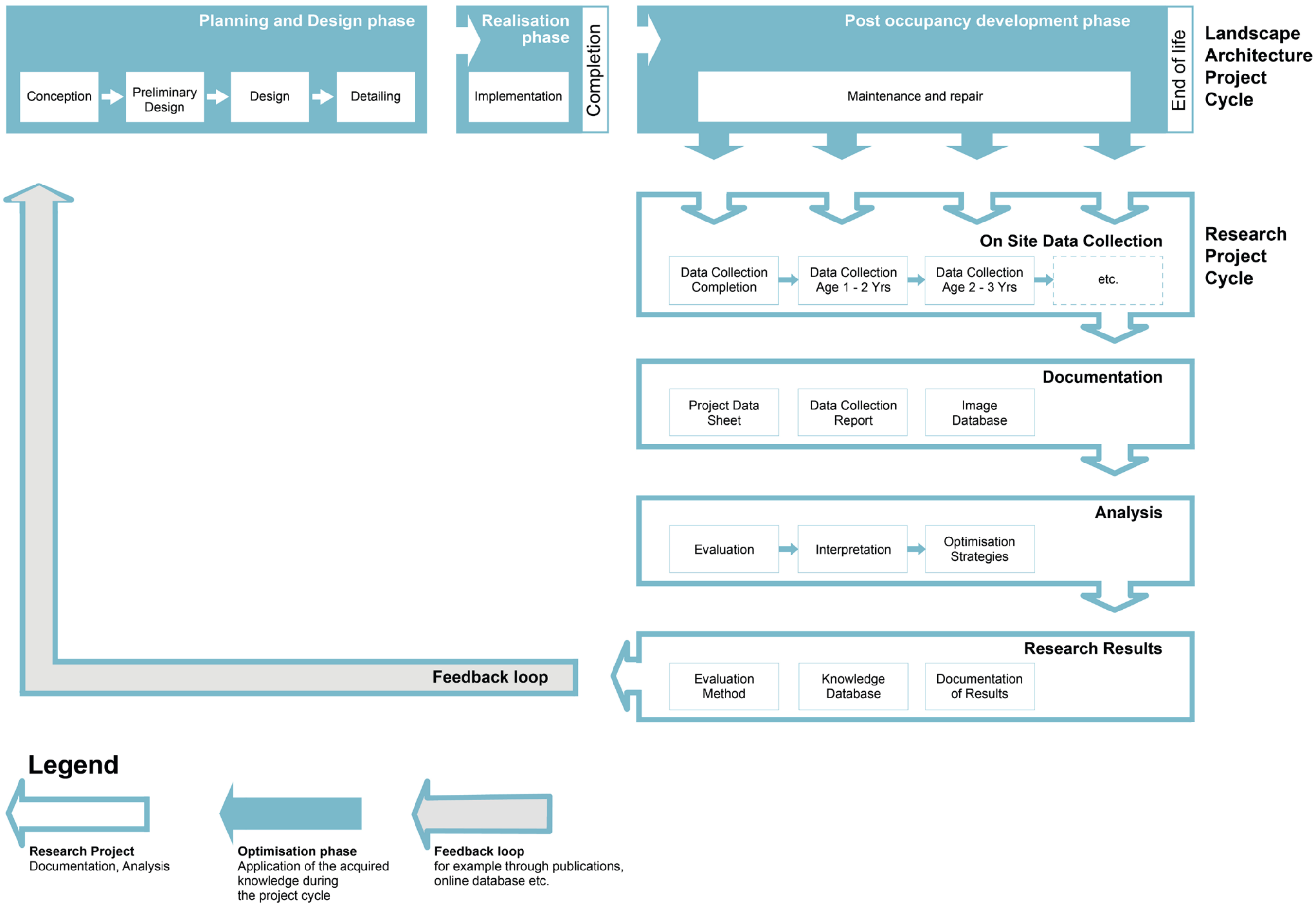


Figure 2

Overview of the research project cycle

fixings). Data collection reports and project data sheets were used to record information from the field studies as well as background data concerning the site itself such as construction periods, location, date of completion, maintenance level, etc. Background data for case studies was obtained from local planning authorities, publications, planning offices and web based resources. The first project-specific multidisciplinary workshop and symposium **'Reading Patina 1.0: Learning from the deterioration of built landscapes through time'** took place within this phase. The international workshop and symposium brought together experts from this field of research to discuss the initial results of the research topic and develop mitigation strategies.

WORK PHASE 3: PREPARE AND MANAGE DATA

In this phase a database was created for storing and retrieving the comprehensive recordings. With the necessary **supplementary recordings** taken during the research period, there were a total of over 90,000 recordings available for evaluation. A screening process was used to critically review and sort the most indicative recorded material. The recordings were then stored in the database and step by step basic metadata (location, project type, completion date etc.) was added.

WORK PHASE 4: ANALYSIS AND INTERPRETATION OF THE DATA

In work phase 4 the identification of frequently occurring points of weakness and vulnerability was carried out by qualitative and quantitative analysis of the data collected. The multi-temporal images from the database that clearly portrayed weak points and vulnerabilities were then grouped for each landscape element to form **case studies** and then chronologically ordered as **sequences**. Over 600 case studies (approximately 17,000 images) were selected and assigned additional descriptive metadata in order to form data sets for the subsequent analysis (Fig. 3).

Multidisciplinary expert interviews and evaluations with landscape architects, landscape contractors and researchers took place in order to carry out the condition classification, determine the most probable causes (root cause analysis), and develop optimisation strategies. The expert interviews were subdivided into three parts:

1. Case study analysis using visual prompts (case study example see Fig. 4)
   Condition Classification form I (very good) to V (not given, unsafe, irreparable) for to the following criteria:

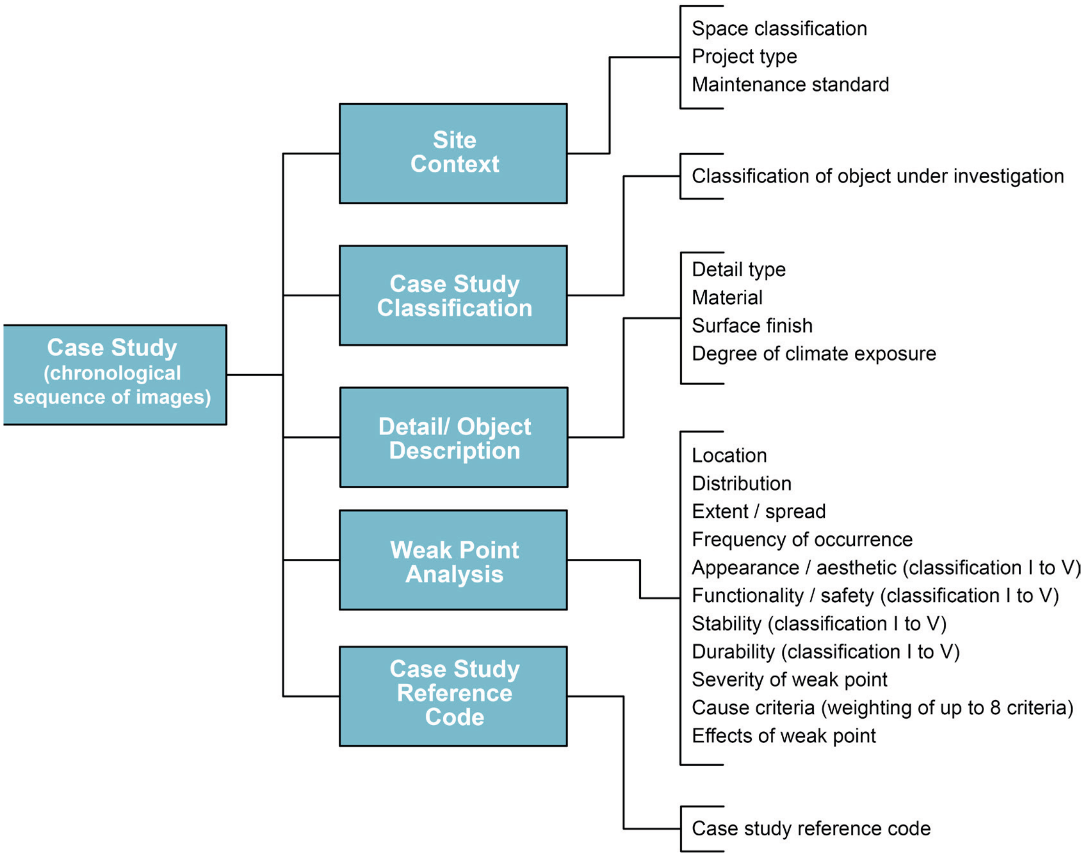


Figure 3

Data base overview.

Functionality: Usability, function, process-related serviceability and safety
Stability: The carrying capacity of the structure at the time of the survey
Durability: The ability of structure to withstand scheduled use through expected service life

2. Root cause analysis:
   a) The root causes of change were assessed according to the factors listed in Fig. 1
   b) Weighting of the evaluation criteria (checklist)
3. The development of possible **optimisation, prevention** and **protection strategies**

The interviews concluded with a general discussion on the strengths and weaknesses of contemporary landscape architecture works - observations, problems, and solutions.

The prioritisation (weighting) of the individual evaluation criteria highlighted the key priorities of each expert. This enabled the main causes to be determined and recommendations for the most appropriate course of action to be developed from varying professional perspectives. The results highlight the perspectives of each stakeholder group, leading to a better understanding of both individual and shared values, priorities and concerns.

Figure 4

Change to wooden bench under a tree canopy over 7 years.
a) Year of completion
b) 1 year later
c, d) 7 years after completion

Project Phase	Category	Cause criteria
PLANNING	Context	**Site and contextual factors** Change/decay due to degree of exposure, aspect, access and circulation etc.
	Component Quality	**Design and detailing factors** Change/decay due to due to quality of design, detailing and durability features
		Material specific factors Change/decay due to material suitability and/or quality.
EXECUTION		**Implementation factors / workmanship** Change/decay due to quality of implementation, workmanship (conformance with construction standards and guidelines)
OCCUPANCY, IN USE	Operating conditions	**Environmental processes / weathering** Change/decay due to environmental processes
		User actions / usage Change/decay due to intensity of use and/or misuse (physical stress caused by humans, animals, plants, vehicles etc.)
		Maintenance and repair Quality and frequency of maintenance and repair
		Force majeure Level of impact of incidents such as flooding, fire, riots etc.

Figure 5

The agents of landcape transformation. [Kirkwood, 1999: 166-177; Colwill, S. (2016): 398].

WORK PHASE 5: DEVELOPMENT OF OPTIMISATION, PREVENTION AND PROTECTION STRATEGIES

The objective of the fifth phase was to develop prevention, minimisation and protection strategies for the weak points and vulnerabilities identified in phase 4. Based on the findings of the interdisciplinary expert interviews, strategies that counteract the weak points and vulnerabilities were developed. The results were represented in the form of texts, drawings, diagrams, recommendations and checklists. The second project-specific multidisciplinary workshop and symposium **'Reading Patina 2.0: Zeit und Veränderung'** (time and change) took place within this phase.

WORK PHASE 6: SUMMARY AND DISCUSSION OF THE RESULTS

In this phase the research results were summarised and scientific conclusions presented. The results were presented in relation to the initial research questions as well as their implications for planning, construction and maintenance practices in landscape architecture. Starting points for future research were also identified in this phase.

WORK PHASE 7: COMPILATION OF THE RESEARCH REPORT

The last phase focussed on the compilation of texts and diagrams for the research report.

4.3 Deviations from the original plan

The project specific workshops and symposiums enabled a broader discussion of the research topic from differing perspectives; many new aspects were brought to the discussion. This led to the development of additional outcomes focussing, for example, on enhancing teaching methods.

The expert interviews not only broadened the focus and depth of the research, but also led a rethinking of terminologies and an adjustment of the evaluation methods. The selection and sorting of case studies was also discussed and modified.

Difficulties were encountered in verifying background data for the case studies (completion dates and other background information); repeated requests to local authorities often remained unanswered. We have therefore also pursued alternative approaches, such as contacting planning offices or searching through web based archives.

4.4 Presentation of results and discussion of the relevant research situation

The case study evaluations display a great diversity of weak points and vulnerabilities throughout public space in Berlin and generated a wide range of detailed knowledge on project development. The repetitive nature of these weaknesses underline a distinct lack of knowledge within the profession on the processes and mechanisms influencing change through time (Colwill: 2018c).

The agents of landscape transformation are interrelated and complex. The following list of main cause criteria was based on standard categories for cause-effect analysis, modified through an initial analysis of 400 selected case studies, and verified through expert interviews and evaluations. These criteria are ordered according to the Project Phase and subdivided into those relating to the Context, Component Quality, and Operating Conditions. Due to the complex nature of these processes some of the criteria inevitably overlap with one another (Fig. 5) (Colwill, 2016: 398; Colwill, 2017b: 295)

MONITORING METHOD:

Monitoring enables patterns in a stream of data to be identified enabling the user to forecast what will happen in the future. The causal analysis method developed in this research project is based on similar systems for the visual inspection of engineering works and is reliant on the judgement of experts (e.g. RI-EBW-PRÜF: 2017, DIN 1076:1999, ISO 15686-8:2008(E), Suda et al: 2007). This can be effectively implemented by one person with sufficient knowledge; however a minimum of 3 team members with differing expertise provides more reliable results. The analysis team may include researchers and practitioners; each brings individual expertise into the team in order to cover the technical spectrum of the works. The monitoring method consists of a four-step evaluation process, firstly defining the problem, secondly assessing the current condition of each landscape element, thirdly carrying out a root cause analysis and finally developing optimisation, prevention and protection strategies.

1) DEFINITION OF THE PROBLEM

The weak point or vulnerability initially needs to be identified and precisely defined. Data is gathered concerning the sequence of events leading to the problem, the time it has taken to develop and the specific conditions for its occurrence. Supplementary data is collected concerning the specific location, usage, exposition, material, construction periods etc.

2) CONDITION CLASSIFICATION

The condition assessment grades characterise the current condition of the structure. Change is classified into those which are purely cosmetic and those that lead to a reduction in functionality, stability, and/or durability. The

		Condition classification criteria				
		I	II	III	IV	V
Category	**Evaluation criteria**	Patination →			Deterioration →	
Functionality	Usability, function, process-related serviceability and safety	Very good / safe	Given, minimal impairment, safe	Given, minor disorders, safety is still given.	Given, major disorders, safety is no longer fully given.	Not given, not operational and/or unsafe
Stability	The carrying capacity of the structure at the time of the survey	Very good	Given, minor symptoms	Given, minor structural problems	Given, major structural problems	Not given / structurally unstable and/or unsafe
Durability	Ability of structure to withstand damaging impacts through expected service life,during scheduled use and maintenance	Very good	Given, minimal impairment	Given, minor impairment	Given, major impairment	Not given

Condition classification in Total I-V
The overall condition classification is equal to the highest individual factor

Figure 6

Condition classification method.

		Condition classification				
		I	II	III	IV	V
Severity	Classification of impairment: Intensity of change, impairment and/or damage	Cosmetic / insignificant	Minor / minimal impairment	Medium / non-critical impairment	Major / substantial impairment	Criitical / fatal impairment
Priority	Urgency of the required remediation	Very low	Low (long term)	Medium (medium term <2 years)	High (short term <1 year)	Immediate
Remediation measures	Remediation measures Maintenance and/or repair	Routine maintenance required	Routine maintenance and/or repair required	Increased maintenance and/or repair required	Urgent remediation required	Immediate comprehensive repair or reconstruction required

Figure 7

Derivation of remediation measures.

case study is valued and interpreted to correspond to the in-use condition grades from I (very good) to V (not given, failure) through qualitative assessment of the factors depicted in Fig. 6. The overall condition classification is equal to the highest individual condition grade. This allows for the images to be sorted into sequences depicting the development of individual weak points and vulnerabilities from condition grades I to V. Each image sequence forms a case study that can be used in forecasting change in similar situations in future projects or for constructional inspections.

From the condition classification, direct remediation measures and their urgency can be derived as shown in Fig. 7. This evaluation also allows conclusions to be drawn about the effectiveness of maintenance and repair.

3) ROOT CAUSE ANALYSIS

This method is based on the European Standard for root cause analysis EN 62740:2015. The causes are identified by expert judgement based on the following **cause-and-effect diagram** (also called the 'Ishikawa' or 'fishbone' diagram). The weak point or vulnerability (effect) is depicted on the right; potential causes can be traced back to the left; branching off for each cause criterion, with sub-branches for secondary and root-causes (Fig. 8, see overleaf).

Weighting of the individual cause criteria allows for a cause profile diagram to be created. The rating 'High' denotes a factor that has a major and/or critical impact on the weak point, 'Low' denotes a factor that has a minor impact, 'Insignificant' is used to describe factors that have little or no impact (Fig. 9).

The weighting of the individual causes also relates to point values. The results of the root cause analysis team are added together in order to generate a cause criteria profile diagram, providing an overview of the most relevant causal factors (Fig. 10).

Project Phase	Category	Cause criteria	Weighting of the criteria			
			0 Insignificant	1 Low (minor cause)	2 Medium	3 High (major cause)
PLANNING	Context	**Site and contextual factors** Change/decay due to degree of exposure, aspect, access and circulation etc.				
PLANNING	Component Quality	**Design and detailing factors** Change/decay due to due to quality of design, detailing and durability features				
PLANNING	Component Quality	**Material specific factors** Change/decay due to material suitability and/or quality.				
EXECUTION	Component Quality	**Implementation factors / workmanship** Change/decay due to quality of implementation, workmanship (conformance with construction standards and guidelines)				
OCCUPANCY, IN USE	Operating conditions	**Environmental processes / weathering** Change/decay due to environmental processes				
OCCUPANCY, IN USE	Operating conditions	**User actions / usage** Change/decay due to intensity of use and/or misuse (physical stress caused by humans, animals, plants, vehicles etc.)				
OCCUPANCY, IN USE	Operating conditions	**Maintenance and repair** Quality and frequency of maintenance and repair				
OCCUPANCY, IN USE	Operating conditions	**Force majeure** Level of impact of incidents such as flooding, fire, riots etc.				

Figure 9

Criteria weighting diagram.

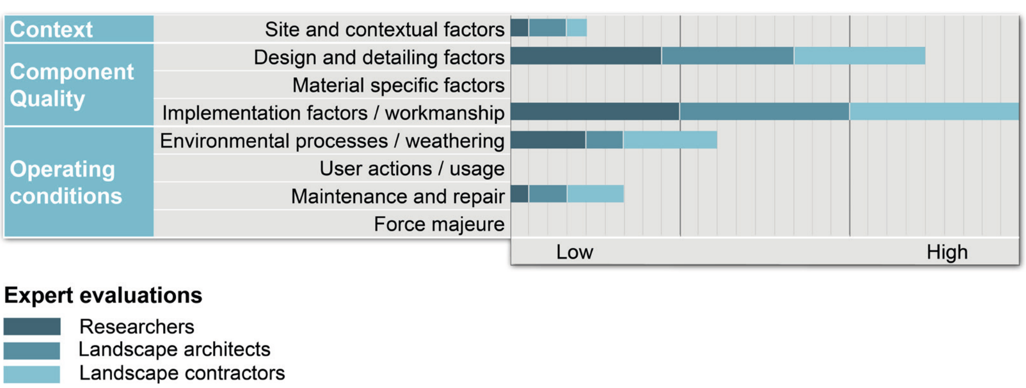


Figure 10

Example of a cause profile diagram. Example evaluation from a root cause analysis team consisting of 9 persons from 3 stakeholder groups.

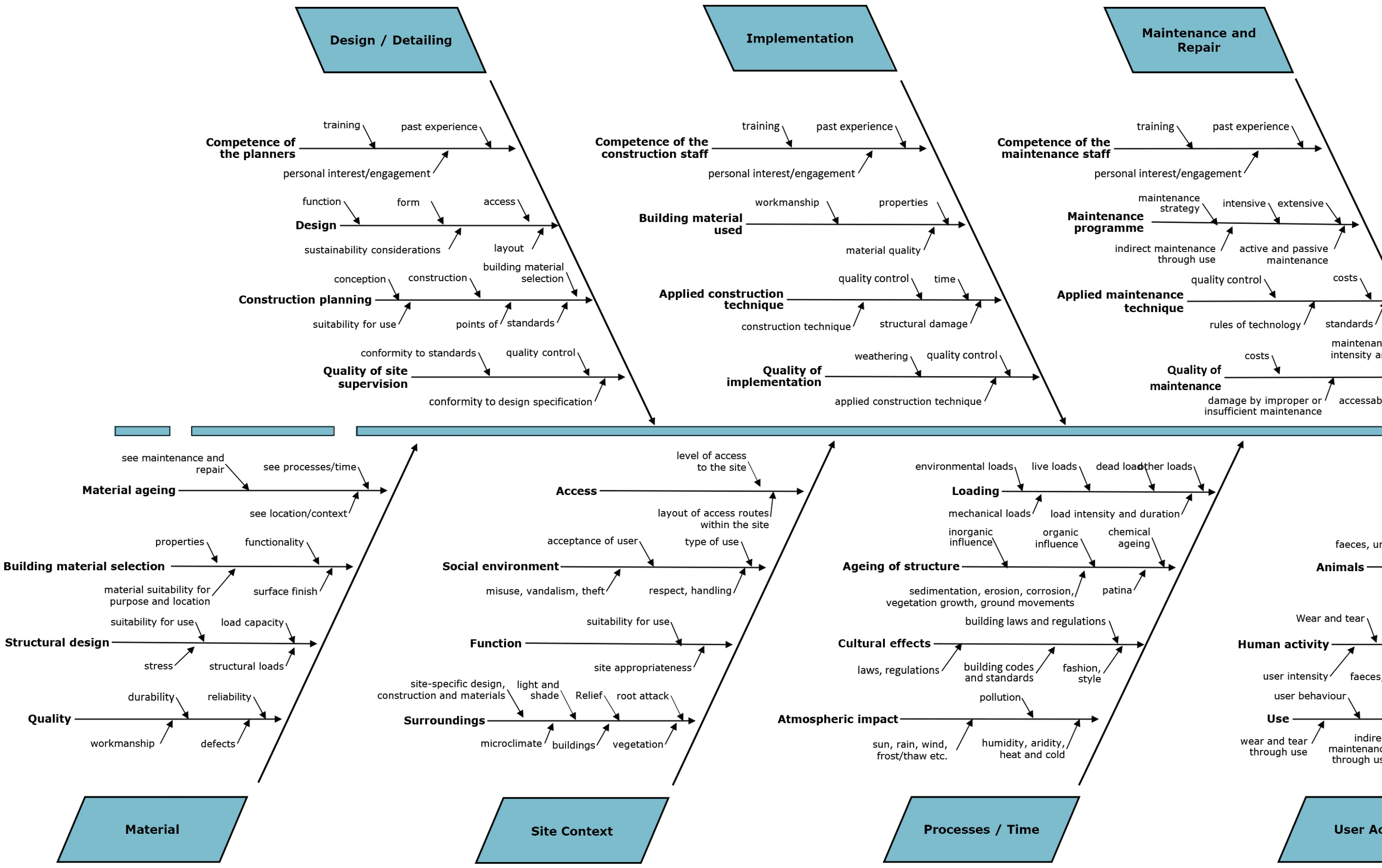


Figure 8

Cause-and-effect diagram for the root cause analysis

The results of the root cause analysis enable the key stakeholders responsible for the implementation of optimisation strategies to be determined (Fig. 11).

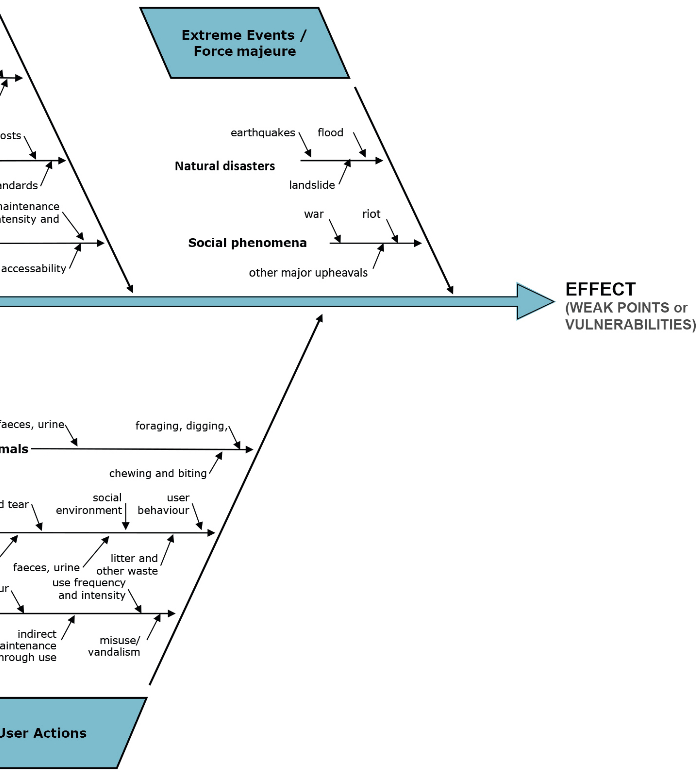
4) OPTIMISATION, PREVENTION AND PROTECTION STRATEGIES

The analysis team develop solutions based on the data available which can be implemented in the design, construction and maintenance phases of future projects. Root causes are those that, once resolved, prevent the undesirable effect from recurring; by dealing with the symptoms or secondary-causes the problems will merely be optimised. Continued monitoring is necessary in order to document the effectiveness of the solutions.

CONCLUSION

A quantitative analysis of the case study evaluations from nine experts (3 landscape architects, 3 landscape contractors and 3 researchers) revealed the key causes of weak points and vulnerability in the selected case studies (Fig. 12). When the total sum of the evaluations for all built landscape elements is considered (143 case study evaluations), deficiencies in design and detailing (65%) were seen to be the main cause of weaknesses followed by maintenance (56%), material specific factors (45%) and the site and context (40%). In contrast, implementation factors (33%) were less frequently regarded as a key cause for deterioration. Insufficient maintenance is a key factor in a large percentage of the case studies analysed in this research. However, landscape architects are responsible for design and detailing, for addressing the site and context, and also for the appropriate specification of materials, and are therefore by far the main stakeholder responsible for implementing optimisation strategies. The main findings of the expert evaluations are documented in the Catalogue of Weak Points and Vulnerabilities (see Appendix A1).

These monitoring and evaluation methods enable the identification of the most frequently occurring points of weakness and vulnerability in built landscape works, the pinpointing of causes and development of possible solutions. The study provides new knowledge on the cause and effect of change to built landscapes through time and in optimising design, detailing, maintenance and management strategies. The results of the case study



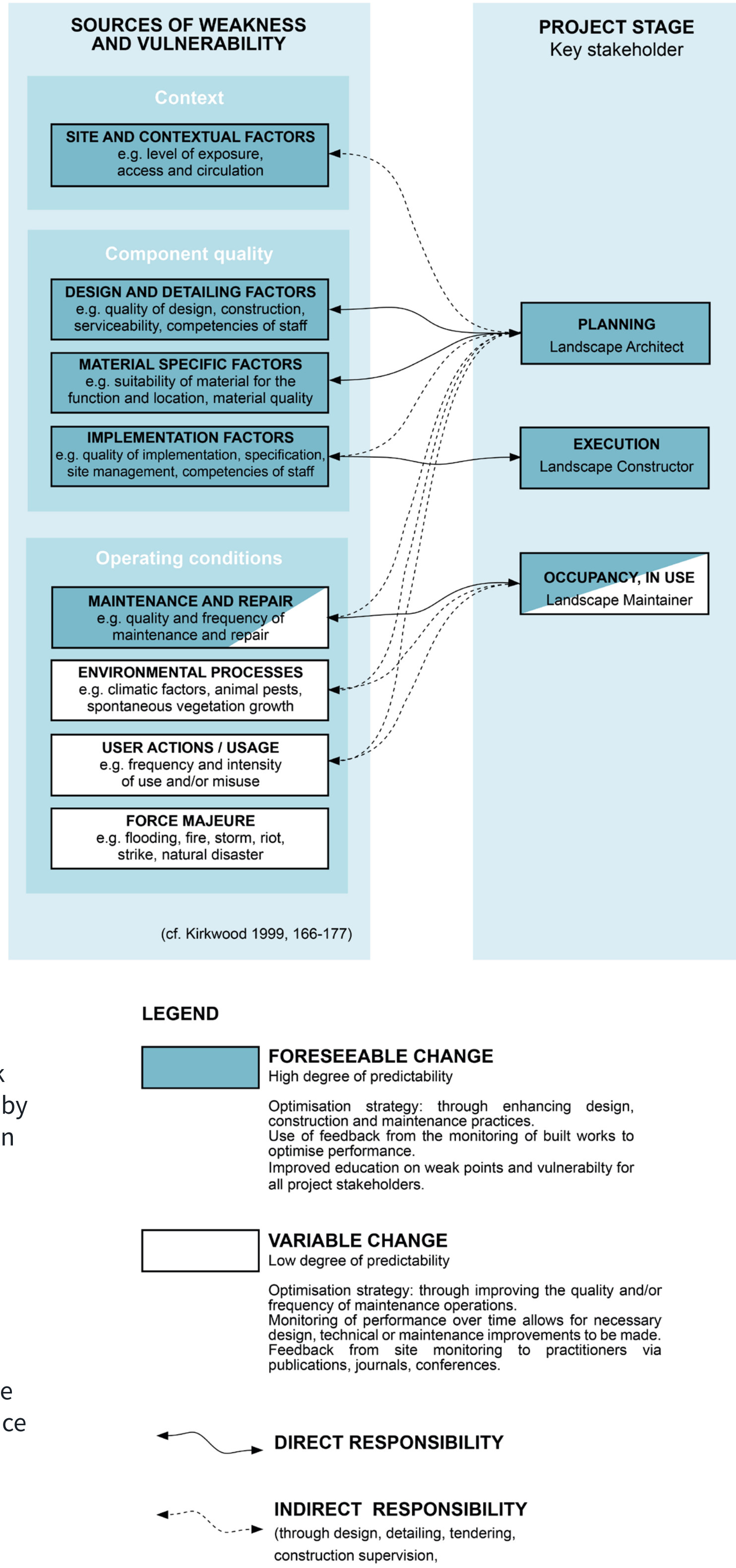


Figure 11

Key stakeholders for the implementation of optimisation strategies.

evaluations are being compiled as a catalogue of weak points and vulnerabilities. This catalogue can be used by practitioners at all phases of the planning, construction and occupation cycle in order to forecast change in the design phase or for supporting constructional inspections (Fig. 13).

The research shows that many problems related to use become visible within the initial 2 years after completion, some however become evident over longer periods. In order to improve operation, optimise maintenance and to measure and optimise performance a four step post completion monitoring system over a period of five years is suggested. We recommend that this should be implemented in year 1, 2, 3 and 5 after completion and cover the following topics:

- Technical analysis:
    - the identification and documentation of existing and developing weaknesses related to usage, design, construction etc.
    - the identification and documentation of performance issues.

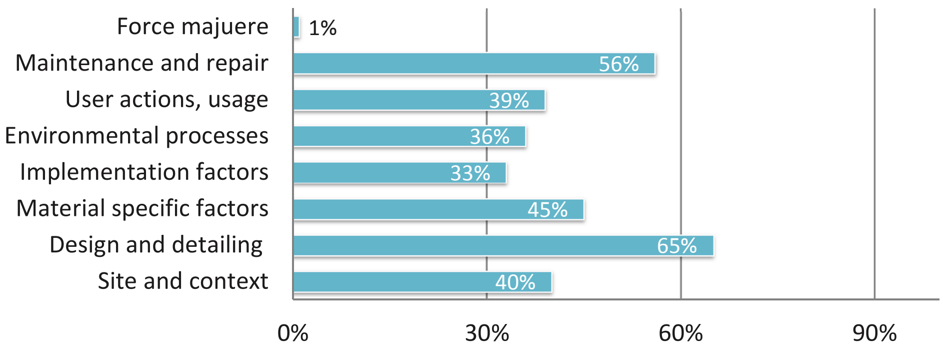


Figure 12

Total cause analysis values involving 143 case studies of built landscape elements.

Figure 13

Overview: Catalogue of weak points and vulnerabilities

    - assessment of the consequential damage/ effects if not improved or repaired.
- Remedial works:
    - adjustment and or optimisation of maintenance regimes.
    - planning of remedial works.
- Optimisation suggestions
    - suggestions for design and/or constructional changes.

The results of this monitoring need to be fed back to the profession in order to be used in optimising future projects. (Colwill: 2018b)

The research results point towards education as one of the key priorities for improving the understanding of weathering, durability and time based change within the profession, and therefore, for optimising the durability and sustainability of contemporary landscape architecture projects (Colwill, 2016: 399-400; Colwill, 2018c). Without learning from past problems, and passing this knowledge on to others through publications and teaching, they will continue to be repeated. This is shown by the repeated occurrence of many weaknesses and failures observed throughout our field research. This research provides the methods and tools for learning from the processes of change, thus solving problems before they arise or escalate. 'Lifelong learning' from built works should become a standard part of 'research and development' within the profession (Colwill, 2017b: 306).

A full description of the research outcomes including the monitoring methodology and case study catalogue will be presented in the PHD publication of Simon Colwill. A publishing house is also interested in publishing the case study catalogue as a reference handbook for practitioners.

4.5 Conceivable follow-up research

1) LONG-TERM RESEARCH

The results of this study would be enhanced through the continuation over a longer period of time. Furthermore, a repeated research period every 1-2 years would allow for the continuous monitoring of project development over time as part of a permanent program.

2) OPEN-SOURCE ONLINE DATABASE OF WEAK POINTS:

This involves the development of a confidential open-source online database for the dissemination of specific knowledge related to innovation, weakness and deterioration in landscape architecture projects (Colwill, 2017b: 308) (Fig. 14).

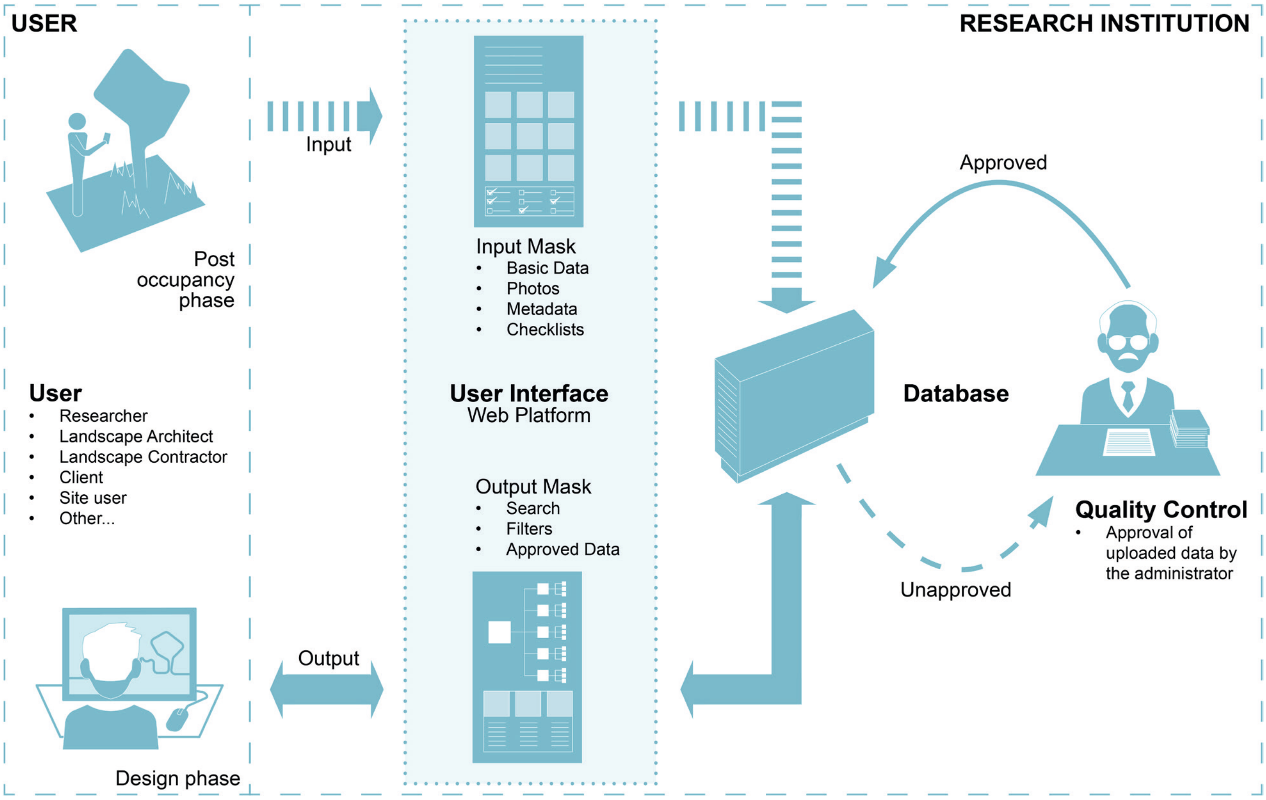


Figure 14

Overview of the open-source online database.

The online database would be set up as a catalogue depicting and analysing change processes as a reference for designers, construction and maintenance firms, and clients. This could be used as a forecasting instrument for planning future projects or for constructional inspections. This platform would need to be administered to ensure that quality control requirements are met.

3) THE PERFORMANCE OF PLANTINGS OVER TIME:
A study focussing on the development of vegetation over time in public space would generate new information on the performance of urban plantings. This could be carried out using similar research and analysis methods to those of this project.

4.6 Economic value of the results

The results of the project are economically exploitable in terms of rights of use. The extensive database with over 90.000 entries together with 600 case studies forms a basis for further diverse research projects and teaching activities in this field. The scientific theories and methods have an indirect value for all related academics and practitioners. Indirect economic value is also generated through the enhancement of teaching methods as a result of this research (see Colwill, 2018c). Public open space authorities (park departments) especially can use the research results on a large scale for optimising the execution of projects, reducing maintenance expenditure and for the long-term allocation of financial resources.

4.7 Project staff and partners who have contributed to the results

The project leader Simon Colwill was the main contributor to the results of the project under the guidance of Prof. Cordula Loidl-Reisch. He carried out the photographic recordings, developed the research methods, carried out the expert interviews and evaluations, prepared the documentation, and published the results. The research methods and results of the research project will be expanded on in his soon to be completed doctoral thesis. The management of the database, analysis of the case studies and organisation of the conferences took place with the support of student assistants Damaris Lory and Lisa Reis. Student assistants Carolin Achtel and Florian Rüster supported the presentation and documentation of project results. We wish to thank Prof. Niall Kirkwood of Harvard Graduate School of Design, (USA) for his advisory support throughout this research project.

The following persons took part in the expert interviews and evaluations:

Researchers

Prof. Cordula Loidl-Reisch: TU Berlin
Prof. Peter Petschek: Hochschule für Technik Rapperswil (Switzerland)
Dipl.-Ing Astrid Zimmermann: lecturer, specialist book author and Zplus Landschaftsarchitektur, Berlin

Landscape Architects

Dipl.-Ing Lioba Lissner: HochC Landschaftsarchitekten, Berlin
Dipl.-Ing Eike Richter: LA-BAR Landschaftsarchitekten, Berlin
Dipl.-Ing Till Rehwaldt: President of the Association of German Landscape Architects (BDLA), Rehwaldt Landschaftsarchitekten, Dresden

Landscape contractors

Dipl.-Ing Detlev Dahlmann: D² Gartengestaltung- und Landespflege
Dipl.-Ing Melanie Kirsch: Melanie Kirsch Garten- und Landschaftsbau, Lecturer at the Lehranstalt für Gartenbau und Floristik (LAGF),
Dipl.-Ing Gaissmaier: Gaissmaier Landschaftsbau, München

Many other international and national partners have supported the project by holding lectures or moderating at our research conferences and workshops, assisting in the development of the research methodology or through supporting the documentation of results.

International partners

Prof. Niall Kirkwood, FASLA: Harvard Graduate School of Design, (USA)
Barbara Deutsch, FASLA: Executive Director of the Landscape Architecture Foundation (USA)
Megan Barnes: Program Manager, Landscape Architecture Foundation (USA)
Assoc. Prof. Liat Margolis: Specialist book author and Associate Professor of Landscape Architecture, University of Toronto (Canada)
Dr. Noël van Dooren: Van Hall Larenstein University of Applied Sciences, Velp (Holland)
Alistair McIntosh: Lecturer, Harvard Graduate School of Design, (USA)

National partners

Dr. -Ing Florian Bellin-Harder: University of Kassel
Dr. Bettina Wettstein, University of Kaiserslautern
Dipl.-Ing Mathias Laszkiewitz, Lehranstalt für Gartenbau und Floristik (LAGF)
Dipl.-Ing Gerd Holzwarth, Holzwarth Landschaftsarchitektur, Berlin
Prof. Dr. Norbert Kühn: Fachgebiet Vegetationstechnik und Pflanzenverwendung, TU Berlin
Dr. Marco Otto: Fachgebiet Klimatologie, Prof. Dr. Scherer, TU Berlin
Dr. Björn Kluge, Joachim Buchholz: Chair of soil protection, Prof. Dr. Wessolek, TU Berlin
Dipl.-Ing Sophie Holz, Fachgebiet Landschaftsarchitektur Entwerfen, TU Berlin
M.Sc. Joshua Brook-Lawson, Fachgebiet Landschaftsarchitektur Entwerfen, TU Berlin
Dipl.-Ing Kristina Schönwälder, Fachgebiet Landschaftsbau-Objektbau, TU Berlin
M.Sc. Florian Zwangsleitner, Fachgebiet Landschaftsbau-Objektbau, TU Berlin

4.8 Qualification of young researchers

The cumulative doctoral thesis of BA (Hons) Dip (Hons) Simon Colwill is almost complete and will be published online by the TU Berlin University Press. The main reviewer of the PhD thesis is Prof. Cordula Loidl-Reisch, the second reviewer is Prof. Niall Kirkwood, Harvard Graduate School of Design, USA.

Master theses were also supervised within the framework of this research project:

J. Naumann: Consequential maintenance costs as a strategic element in the design process.
S. Wolf: At what point does maintenance cease and renovations begin?
J. Richter: 'Steel - Time - Change' - steel in public open space.
N. Mayr: Mischief. Crime. Wilful destruction - Vandalism!
H. Mau: Between overuse and underuse of public space.
D. Jiménez van Aaken: Wood; durable and comfortable.

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BMUB-Berlin (Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit) (Ed.) (2015): *Grün in der Stadt - Für eine lebenswerte Zukunft. Grünbuch Stadtgrün*, Berlin: Self-published

COLWILL, Simon (2016): *Time, Design and Construction: Learning from Change to Built Landscapes Over Time. In Bridging the Gap.* ECLAS Conference 2016, Rapperswil, Switzerland. Conference proceedings. ISSN 1662-5684, ISBN 978-3-9523972-9-9.

COLWILL, Simon (2017a): *Climate and Decay: The impact of the urban climate on built landscape.* ECLAS Conference 2017, University of Greenwich, London UK. Conference proceedings, pp. 315-332.

COLWILL, Simon (2017b): *Time, Patination and Decay. In Creation/Reaction.* ECLAS Conference 2017, University of Greenwich, London UK. Conference proceedings, pp. 293-314. ISBN: 978-0-9935909-6-2.

COLWILL, Simon (2018a): *The Root of the Problem: Addressing the Conflicts between Spontaneous Vegetation and Built Landscape.* ECLAS Conference 2018, University College Ghent, Belgium. Conference proceedings (in press)

COLWILL, Simon (2018b): *Use and Abuse: Reading the Patina of User Actions in Public Space.* ECLAS Conference 2018, University College Ghent, Belgium. Conference proceedings (in press)

COLWILL, Simon: *Teaching Landscape Construction: On-site learning.* In: Routledge Handbook of Teaching Landscape (2018c). Elke Mertens (Editor), Nigul Karadeniz (Editor), Karsten Jorgensen (Editor), Richard Stiles (Editor), [S.l.]: Routledge. ISBN-13: 978-0815380528, ISBN-10: 0815380526 (in press). Publication planned: autumn 2018

DIN 1076 (1999): *Engineering structures in connection with roads- inspection and test. Deutsches Institut für Normung.* Berlin: Beuth.

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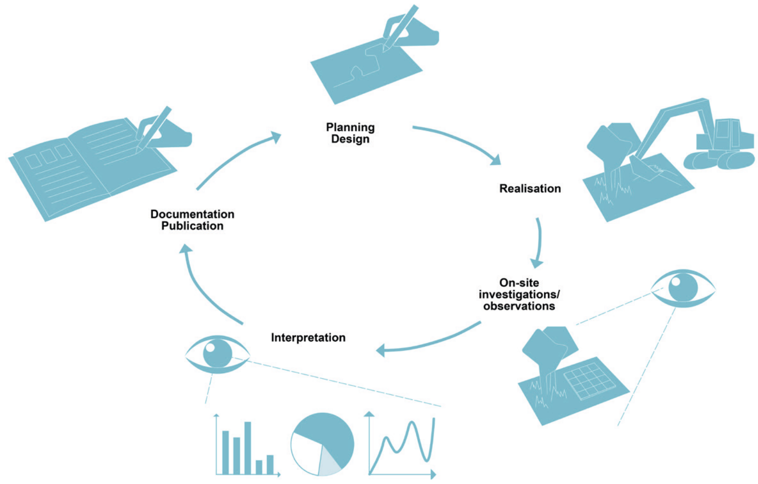
SUDA, J., SICHER. P., LAMBRECHT, D.: *Zustandserfassung und -bewertung von Schutzbauwerken der Wildbachverbauung – Teil 1 – Schädigungsmechanismen, Bauwerkserhaltung.* Schriftenreihe des Departments für Bautechnik und Naturgefahren, Band 15 (2007), Vienna: Self-published.

WATT, David (1999): *Building pathology. Principles and practice.* Malden, Mass: Blackwell Science.

YIN, Robert (2014): *Case Study Research: Design and Method,* 5th edition (first edition, 1984), Sage Publications, Los Angeles.

KIRKWOOD, N. (1999): T*he Art of Landscape Detail.* Fundamentals, Practices, and Case Studies: Wiley

5 SUMMARY



This practice orientated research aimed at optimising the performance of future built works through analysing the weak points and vulnerabilities of existing built landscape architecture works. Built landscape architecture works are dynamic evolving systems interacting with the natural environment and patterns of use. The process of patination and subsequent deterioration of built landscapes highlight weak points of the design as well as deficiencies in detailing, construction and maintenance. These processes however can also inform practitioners on the implications of design, detailing, usage, weathering and maintenance. The current poor state of many built landscape architecture projects justifies the need for more effective monitoring and feedback from built works. In this research, the time-bound behaviour of contemporary landscape architectural elements in the city of Berlin was examined based on a non-destructive multi-temporal analysis under the prevailing contextual conditions. The 'built landscape elements' central to this research are for example steps, paths, edgings, drainage elements, tree grates, seating elements, fences and walls.

Weak points are areas of a structure that due to the design, construction, particularly exposed location (corners, edges etc.) or particularly high demands (surfaces with ground contact etc.) are of especial vulnerability. Inherent weaknesses are an unavoidable factor of all structures resulting from the design, material properties or wear and tear (e.g. the corner of a table). Weaknesses can however also be caused by misjudgements in the planning and execution of the design, low quality materials or by poor workmanship and maintenance. Weaknesses can be minimised or avoided through learning from previous failures by monitoring project development and providing feedback to the profession. Many frequently occurring points of weakness and vulnerability were identified throughout this research. The repetitive nature of these weaknesses underlines a distinct lack of knowledge within the profession of the processes influencing change through time.

Annually repeated photographic surveys of changes to the built landscape elements in three zoom factors - context, object, and detail images, – form the basis for the subsequent analysis and evaluation. The core period of research covered the first 5-8 years of post-completion project development, further one-off surveys of older projects allowed for a period of up to 25 years to be analysed. The photographic recordings were assigned metadata (e.g. location, completion date, facility, material), grouped as case study sequences, and stored in a database. Through comparisons between the original state and successive recordings, process-dependent changes became visible and frequently occurring points of weakness and vulnerability were pinpointed. Comparisons of the rate of change allowed premature ageing to be determined, and the most significant causes identified.

The methodology was verified through multidisciplinary expert evaluations of 159 identified weaknesses and vulnerabilities involving nine persons from three stakeholder groups; landscape architects, contractors and researchers. A quantitative analysis of the results revealed that deficiencies in design and detailing (65%) were seen to be the main cause of weakness, followed by maintenance (56%), material specific factors (45%) and the site and context (40%). In contrast, implementation factors (33%) were less frequently considered a key cause for deterioration. Landscape architects are therefore by far the main stakeholder responsible for implementing optimisation strategies.

Key research results are presented in a catalogue of weak points and vulnerabilities, thus providing practitioners with a tool for informing their judgments on design, detailing and maintenance. The results benefit all stakeholders in the field of landscape architecture by generating a breadth of new knowledge to enhance the design, construction and maintenance of landscape architecture works. The use of this research enables practitioners to forecast change, thus enhancing the performance of built landscape works and making an important contribution to the sustainability of landscape construction.

The results of the project have been broadly published through publications and presentations at conferences. The Swiss Federation of Landscape Architects (BSLA) journal Anthos reported on the initial research results in 2016. A Newsblog focussing on the results of the research project was recently posted by the Landscape Architecture Foundation (LAF) in USA and an E-Newsletter has been widely posted to over 7,000 readers.

Journal: COLWILL, Simon (2016): *'Von Alterungsprozessen lernen'*, (German, French) In: Anthos. Nr. 3-16, S 31-33. Zürich: Bund Schweizer Landschaftsarchitekten und Landschaftsarchitektinnen.

Blog: COLWILL, Simon (2018): '*Time and Landscape Performance'.* Newsblog / E-Newsletter with over 7000 readers. Landscape Architecture Foundation, USA. Posted 14th August, 2018 as Newsblog and as E-Newsletter. Available at: lafoundation.org/news-events/blog/2018/08/14/time-and-landscape-performance

6 APPENDIX

A1) 'CATALOGUE OF WEAK POINTS AND VULNERABILITIES'

A1-1: Including: Basic data, list of case studies, case study overviews, methods, legend
Chapter Steps: Case study evaluations for steps

A2) PROJECT SPECIFIC WORKSHOPS / SYMPOSIUMS

A2-1: Poster: Reading Patina 1.0: Learning from the deterioration of built landscapes through time

A2-2: Poster: Reading Patina 2.0: Zeit und Veränderung (Time and Change)

Appendix A1-1

COLWILL, Simon (2019): READING PATINA: Catalogue of weak points and vulnerabilities (PART 2). DOI: http://dx.doi.org/10.14279/depositonce-8599

Symposium . READING PATINA

Learning from the deterioration of built landscapes through time

Technische Universität Berlin

Thursday 7th & Friday 8th July 2016

The symposium aims to present an overview of previous and related research on the processes and mechanisms influencing built landscapes through time and how monitoring these processes can inform future projects. Presentations from academic researchers and practitioners will enable a breadth of discussion related to this topic.
The passage of time leaves traces on the surfaces of materials for example in the form of dirt, wear and tear, subsidence, surface cracks and vegetation growth. These processes of patination and decay highlight the imperfections and points of weakness in built landscapes. By monitoring „patina" the project stakeholders can gain information on the success or failure of the design, detailing, use of materials, construction and/or maintenance.
Colleagues from teaching and research, students, construction and maintenance firms, government agencies, clients and other interested individuals are invited to participate in the symposium.

Day 1 - Lectures / 14.30-20.00

Thursday 7th July 2016

The first day is aimed at bringing together existing knowledge, an overview of previous research, as well as information and opinions related to this field of research.

Venue: "Horst-Wagon-Hörsaal", Room H 1012

Day 2 - Lectures + Workshop / 09.30-18.00

Friday 8th July 2016

The second day will focus on the processes and mechanisms influencing change to built landscapes after completion. An interdisciplinary workshop will examine the impact of these processes from different viewpoints.

Venue: to be announced

Preliminary list of speakers

Keynote: Niall Kirkwood „Details of Durability," Harvard Graduate School of Design

Cordula Loidl-Reisch „Built to be wild," TU Berlin

Bettina Wettstein „Landscape Architecture - Design Idea and Realisation" TU Kaiserslautern

Liat Margolis „Smart Landscapes," University of Toronto

Simon Colwill „Reading Patina," TU Berlin

Further speakers to be announced

Contact:
Simon Colwill
Fachgebiet Landschaftsbau-Objektbau
Email: simon.colwill@tu-berlin.de

Participation is free of charge
Pre-registration is required: www.eventbrite.com
More information: www.objektbau.tu-berlin.de

Funded by Deutsche Forschungsgemeinschaft

Appendix A2-1

Poster: Reading Patina 1.0: Learning from the deterioration of built landscapes through time

Zeit und Veränderung | Reading Patina 2.0

Landschaftsarchitektur
Symposium
Lehre | Forschung | Praxis

Interessierte sind zur kostenlosen Teilnahme am Symposium herzlich eingeladen.

Donnerstag, 05. Juli 2018
TU Berlin Erweiterungsbau
Raum EB 414 A
16:30 Uhr

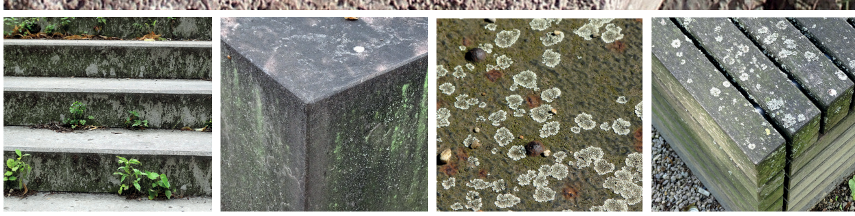
Das Symposium gibt einen Überblick über aktuelle Forschungen zu den Prozessen und Mechanismen, welche im Laufe der Zeit gebaute Landschaftsarchitekturen beeinflussen. Aus den Ergebnissen werden praxisorientierte Strategien entwickelt. Um eine breite Diskussion zu ermöglichen, werden Präsentationen aus verschiedenen Blickwinkeln folgende Themen beleuchten:

Surface Patina: Analyse, Manipulation und Management

Darstellung von Veränderung und Dynamik in der Landschaftsarchitektur

Vegetationsdynamik und Pflegeprognostik anhand von Spuren der Zeit

Schwachstellenoptimierung basierend auf Analysen von Patinierungsprozessen



Fachgebiet Landschaftsbau-Objektbau

TU Berlin
Straße des 17.Juni 145
10623 Berlin

Deutsche Forschungsgemeinschaft

Appendix A2-2

Poster: Reading Patina 2.o: Poster: Reading Patina 2.o: Zeit und Veränderung (Time and Change)

AUTHOR

Simon Colwill

ASSISTANTS

Damaris Lory
Carolin Achtel

Cover photos:
Front: 16 years after completion
Back: 17 years after completion

All figures, photos and diagrams are original works of Simon Colwill unless otherwise stated. Translations by the author.

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http://dx.doi.org/10.14279/depositonce-9407

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Technische Universität Berlin

FINAL REPORT

CHAIR OF LANDSCAPE CONSTRUCTION

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Final report on the DFG-Projekt 242199665, September 2018