# 物联网视角下的建成景观设计项目运行信息管理：从空缺到途径

# IoT-Based Operational Information Management for Built Landscape Projects: From Vacancy to Approaches


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## 摘要

伴随着第四次工业革命下新一代数字技术的快速更迭，数字景观与智慧景观设计已逐步成为设计领域研究的前沿和热点。物联网作为新兴的数字工具，拥有被用于建成景观项目的运行信息管理的巨大潜力。本文以建成景观设计项目的运行阶段为研究对象，以空缺分析及研究述评的方式探讨物联网（IoT）技术辅助项目运行信息管理的途径。本文首先提出运行信息管理的主要目标为开展景观绩效评估和精细化后期管理，进而指出两大数字工具的缺失：生态数据监测工具缺乏和动态景观信息建模工具缺失。本文而后结合已有案例，重点探讨IoT技术辅助生态数据在线监测及动态信息建模的应用路径与相关注意事项。本文同时强调，景观设计师和项目管理者不仅要关注IoT技术的研究动向，更重要的是要明确学科本身的实践需求，以避免落入“为了应用而应用”的陷阱；而面向学科研究的未来时，本文意在揭示行业技术升级将引发需求升级的发展过程，这一升级也将带来景观设计师定位和培养模式的转变，以及景观设计和研究工具的革新。



## 关键词

在线监测；景观信息建模；绩效评估；空缺分析；智慧景观设计；运行信息管理



## ABSTRACT

With the rapid advance of digital technology under the fourth industrial revolution, digital landscape and smart landscape architecture have gradually become the research hot spots in design professions. The Internet of Things (IoT), as an emerging digital tool, has shown great potential to assist operational information modeling for built landscape projects. This article, focusing on the post-operation for built projects, deliberates IoT-based approaches to operational information management (OIM) through vacancy analysis and literature review. It first argues that OIM's main goals are performance evaluation and refined management, and points out the absence of effective monitoring tools for ecological performance and dynamic modeling tools for data storage, analysis, and visualization. Combing with existing cases, it also demonstrates and summarizes the methods for IoT-based ecological performance monitoring and dynamic information modeling, as well as the principles for related application. In addition, landscape architects and project managers should pay attention to emerging research trends of IoT technology, and more importantly, emphasize authentic application scenarios to avoid blind practice. As for the future of Landscape Architecture, this article attempts to reveal the profession development trajectory that technological upgrade leads to demand upgrade, which will also bring about changes in landscape architects' contemporary mission and the methods for talent training, and about the innovations of landscape design and research tools.



## KEYWORDS

Online Monitoring; Landscape Information Modeling; Performance Evaluation; Vacancy Analysis; Smart Landscape Architecture; Operational Information Management

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## 1 引言

伴随着第四次工业革命下新一代数字技术的快速更迭，数字景观与智慧景观设计已逐步成为设计领域研究的前沿和热点。其中，物联网（Internet of Things，简称“IoT”）等数字工具的逐步升级将更好地服务于建成景观项目的运行信息管理（operational information management，简称“OIM”）[1]-[3]。

IoT强调利用无线传感网络（wireless sensor network，简称“WSN”）将各种传感设备与互联网实时连接起来，以达成对物质世界的信息管理。早在2009年美国IBM智慧城市构想[4]及2014年的意大利“帕多瓦智慧城市”技术框架中，基于IoT的智慧城市环境和智慧生活等构想就已被探讨[5]。而在中国提出的新型基础设施建设及双循环经济的战略下，IoT将被更为广泛地应用到中国智慧城市建设和智慧景观设计领域[6]。在国际智慧城市建设方面，IoT已被广泛应用于工业生产、交通货运、能源开采等城市“运行场景”之中[7]，而电子、通讯、计算机等学科正在不断提升数据获取、传输和分析的效率①，以满足运行场景中定量化、实时化的数据交互需求。相比之下，中国景观设计领域开展的针对设计项目的OIM与绩效评估相对较少[8]，而IoT辅助景观项目设计后期的技术途径也尚未获得充分探讨。

本文以建成景观设计项目的运行阶段为研究对象，以空缺分析及研究述评的方式探讨IoT技术辅助项目OIM的途径。本文首先分析了OIM的主要目标，指出两大数字工具的缺失：生态绩效数据获取缺乏有效的监测工具，运行数据存储、分析与呈现缺乏有效的建模工具；并进一步结合已有案例重点探讨IoT技术辅助生态数据在线监测及动态信息建模的方法（图1）。

## 2 建成景观设计项目的运行信息管理目标

信息管理指利用数字技术完成信息需求识别，信息的获取、组织、存储，信息产品和服务的开发、信息的呈现与利用的循环过程[9]。在景观设计项目中，设计师往往将大量精力投入到前期方案阶段，而较少注重对其建成效果实施有计划的信息管理。其直接原因是不同的设计、施工、运营单位所带来的信息管理责任权属的不同致使信息管理边界的形成。一方面，这种各自为政的信息管理模式导致设计者在方案阶段所采取的设计策略（尤其是生态措施）很难预留相应的评估和改进空间，从而使设计中的生态理念趋于概念化，其景观绩效也难以评估检验。另一

① 笔者以“Internet of Things”和“IoT”作为关键词分别检索CNKI及Web of Science数据库的论文构建知识图谱，旨在为景观设计师提供一个基础性的IoT技术框架。通过知识图谱可以将IoT研究体系总结为传感设备与协议问题、数据传输效率与安全性问题、数据分析方法（云计算与机器学习）及IoT应用。“智慧城市”作为IoT的研究与应用热点，要求建筑科学领域利用实时数据完善物理、数字或半实物仿真模型，构建数字孪生系统，以提升建成环境项目的全生命周期的评估与管理。

## 1 Introduction

With the rapid advance of digital technology under the fourth industrial revolution, digital landscape and smart landscape architecture have gradually become the research hot spots in design professions. Digital tools, including the Internet of Things (IoT), are keeping upgrading to better assist operational information management (OIM) for built landscape projects[1]-[3].

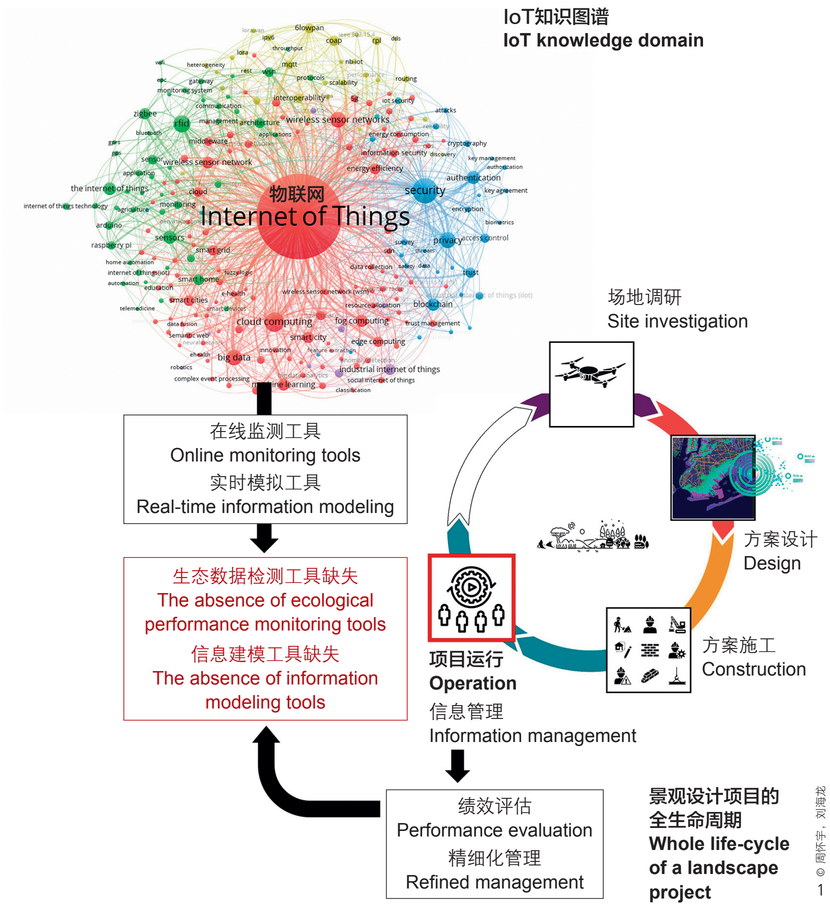
IoT emphasizes utilizing wireless sensor networks (WSN) to establish real-time connection between various sensors with the Internet for the information management of the physical world. As early as the IBM Smarter City Initiative[4] (2009) in the United States and the technical framework for Padova Smart City in Italy (2014), concepts such as IoT-based smart city environment and smart living have been explored[5]. As the Chinese government has proposed tactical agendas on new infrastructure and dual circulation economy, IoT will see a broader application in smart city construction and smart landscape architecture[6]. IoT plays an essential role in urban operational scenarios such as industrial production, transportation, logistics, and energy extraction[7]. Disciplines like Electronic Engineering, Communication Engineering, and Computer Sciences witness constant efficiency improvement in data acquisition, transmission, and analysis to support quantitative and real-time data exchange in operational scenarios. In contrast, OIM and performance evaluation for built projects are less carried out by Chinese landscape scholars[8], especially to help address technical issues in post-operation stage.

This article, focusing on the post-operation for built projects, deliberates IoT-based OIM's approaches through vacancy analysis and literature review. It first analyzes OIM's main goals and points out the absence of effective monitoring tools for ecological data and modeling tools for data storage, analysis, and visualization. Combining with existing cases, it also demonstrates and summarizes the methods for IoT-based ecological data monitoring and dynamic information modeling (Fig. 1).

## 2 Main Objectives of OIM for Built Landscape Projects

Information management refers to a cycle of processes that support "identifying information needs, acquiring information, organizing and storing information, developing information products and services, distributing information, and using information"[9]. Landscape architects often focus on the conceptual design of a project but seldom carry out plans for post-operation OIM. One reason is that

① The authors retrieved research papers with the keywords "Internet of Things" and "IoT" on CNKI database and the Web of Science database and mapped a knowledge domain to provide a primary IoT technology framework for landscape architects. Current IoT research interests include 1) sensing equipment and protocols, 2) data transmission efficiency and security, 3) cloud computing and machine learning, and 4) IoT applications. Smart City is a research hot spot in IoT application. Related disciplines utilize IoT to improve physical, digital, or semi-physical simulation models and establish a digital twin system to improve the built environment's full life-cycle management.

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1. IoT视角下目运行信息管理的空缺分析
1. Vacancy and demand analysis of IoT-based OIM for built landscape projects

方面，由于缺乏设计团队的指导，项目建成后的维护和管理难免与原有方案脱节，阻碍了OIM系统的有效形成。

在国家相关政策及高质量发展的要求下，相关建筑科学领域内的设计、施工、运营各方，以及学界均已逐步认识到项目全生命周期管理的重要性[10][11]。景观设计项目OIM不应再仅仅依赖于管理者，而应由设计方和施工方共同完成。结合中国风景园林学科的当代需求及研究热点，笔者将景观设计项目运行阶段的信息管理的主要目标总结为以下两个方面。

### 2.1 目标一：开展景观绩效评估

作为绿色基础设施，景观项目发挥着供给、调节、支持和文化的生态系统服务，而面向循证设计的景观绩效评估则能为项目设计方、管理者和使用业主提供建成效果的量化科学证据[12][13]。

目前，对于绿色基础设施设计，以介绍为目的的定性研究较多，针对信息采集和评估的定量研究较少[14]。相关研究在较大尺度上描述了绿色基础设施系统的整体生态系统服务评估和优化，而城市等中微观项目尺度的定量测度相对匮乏[15]。针对设计项目的绩效评估，国内外学者对采集指标的探讨还远多于评估方法探索和数字工具开发：无

the information management disjunction between the designer, constructer, and operator of a project, which hinders data sharing. On the one hand, the separate workflow makes landscape architects difficult to formulate specific evaluation and plans to improve the design, ecologically in particular. As a result, genetic ecological strategies are often adopted at a conceptual level which challenges the performance evaluation. On the other hand, due to the absence of guidance from the design team, post-operation maintenance will inevitably be out of touch with the original plan, resulting in the failure of forming an effective OIM system.

Impelled by relevant policies and the High-Quality Development strategy proposed by Chinese government, designers, constructors, and project operators in architectural science, as well as scholars, have ascertained the importance of whole life-cycle management[10][11], and should promote OIM with joint efforts. Considering the current trends and research hot spots in Chinese Landscape Architecture, the authors summarize two main objectives of OIM for built landscape projects.

### 2.1 Objective One: Landscape Performance Evaluation

As part of green infrastructure, landscape projects provide ecosystem services of provision, regulation, support, and culture. Landscape performance evaluation offers designers, managers, and users with quantitative scientific knowledge that support evidence-based design[12][13].

At present, Landscape Architecture finds more qualitative literatures showcasing green infrastructure design, but fewer studies concentrate on quantitative evaluation based on authentic data[14]. Existing research focuses on the evaluation and improvement of overall ecosystem service of large-scale green infrastructure systems, less for middle- or micro-scale landscape projects, especially on quantitative measurement[15]. Moreover, scholars in China and abroad are currently paying more attention to developing evaluation indicators than evaluation approaches and digital tools. International standards like SITES, LEED-ND, and the Landscape Performance Series (LPS) developed by Landscape Architecture Foundation have established a series of evaluation indicators and gained methodological achievements. However, due to the lack of data acquisition methods, the traditional paradigm that relies on designers' investigation on individual cases cannot effectively promote performance evaluation in the profession.

### 2.2 Objective Two: Refined Management

In addition to evidence-based evaluation research, OIM-related new technology can also contribute to the refined management of landscape projects. In recent years, landscape projects are increasingly integrating with digital technology, and many intelligent platforms supporting multiple functions such as ecological protection, energy-saving, emission reduction, and interactive recreation have been developed[16]. These platforms are primarily used to guide the propaganda, post-operation, and refined maintenance of built projects, mainly for demonstrative and interactive purposes. This article does not intend to distinguish similar concepts

论是SITES、LEED-ND等国际评价标准，还是美国风景园林基金会提出的“景观绩效系列”（LPS）研究计划，都已对评估指标进行了充分探讨，并提供了一定的方法论基础。但由于数据获取手段的缺失，依赖设计师自组织的短期调研模式并不能使绩效评估在行业内得到有效推广。

### 2.2 目标二：精细化管理

除进行面向循证设计的绩效评估外，信息管理的新技术还将促进项目的精细化管理。近年来景观项目呈现明显数字化趋势，而服务于生态环保、节能减排、互动游憩等多重目标的智慧信息平台亦逐步涌现[16]。这类平台的核心目标在于指导项目的后期宣传、运营和精细化维护，具有突出的示范性和互动性。本文无意于区分“智慧园林系统”“绿化管理平台”“智慧公园”等相似概念，而是旨在探讨基于上述运行管理目标下的动态信息建模策略。

当前，应用全生命周期管理的景观设计实践案例还较少[17]，且现阶段景观设计数字化升级中信息模型的指导作用不明显。设计和管理模型的脱节及重复开发也使得信息模型的推广倍受限制：设计方案呈现的空间模型、服务于施工的细节模型无法完成项目运行阶段的信息管理工作，这也导致管理者往往需要委托第三方单独开发运行模型；然而大多数第三方平台仅支持静态的电子地图、信息查询和图片展示，较难真正实现数字化管理的功能[18]。

## 3 景观设计项目OIM的数字工具空缺

笔者认为，当前景观设计中OIM的不完善并非缘于政策、意识或理论层面的欠缺，而是相应数字工具的缺失。纵观景观设计的工具体系以及项目设计—施工—运营周期，基于定量—定性方法的设计方案的生成、分析、模拟一直是学科的核心竞争力所在。其中，利用无人机的地形勘测[19]，基于参数化编程的形态生成[20]，基于GIS叠图法的适宜性、多情境分析[21]，基于水文、气象模拟软件的绩效预测[22][23]等研究工具能够为项目提供有力的设计依据，现已在行业内得到广泛应用。这些工具针对的是相对静态的、历史的（单一时刻的）数据，可辅助推敲设计方案，但却很难应用于项目运行阶段的数据处理。因此，为应对项目运行信息管理的要求，学科亟待引入新技术来填补以下两大数字工具的空缺。

### 3.1 有效的生态数据监测工具

景观设计项目运行阶段的使用数据及图像数据并不难获取，但设计师和业主共同关心的生态效益则缺乏有效的监测工具。换言之，景观设计师并不缺少数据筛选和挖掘的机遇，但亟待对生态信息进行主动采集。

在城市规划及建筑设计等领域，社交媒体数据、手机信令数据、城市图像数据等已成为信息管理和应用的主要数据来源。其优势在于目前城市获取这些数据的条件较为完善，从用户的智能手机到无人机和城市摄像头，都可能成为信息采集的工具[3]。而图像分析、统计分析、空间叠加分析和机器学习等方法也已在信息管理领域形成一定的研究范式。

such as “smart landscape system,” “greening management platform,” or “smart park,” but aims to explore strategies of dynamic information modeling for the improvement of post-management.

At present, there are few cases of whole life-cycle management in design practice[17], and the superiority of OIM in landscape design has not been fully demonstrated. The disjunction or function overlap of design and management models also limits the promotion of OIM. For instance, spatial models for design presentation or detail construction models often cannot be utilized for OIM directly, when a new OIM model needs to be developed by a third party. However, most existing third-party platforms only support static maps, information queries, and picture displays that cannot meet the requirement for digital management[18].

## 3 The Gaps of Digital Tools for OIM of Built Landscape Projects

The authors believe that the unsatisfactory application of OIM in Landscape Architecture is ascribed to the absence of digital tools, instead of the inadequacy in policy, awareness, or theoretical research. Considering existing landscape design toolkits and projects’ life cycle of design–construction–operation, integrating quantitative and qualitative methods for strategy generation, design analysis, and performance simulation will leverage the discipline’s core competitiveness. Digital tools can provide evidences for landscape design research, some of which have been widely applied, such as the use of unmanned aerial vehicles (UAVs) for terrain survey[19], morphology generation by parametric programming[20], suitability and multi-scenario analysis based on GIS mapping[21], and performance prediction with hydrological and meteorological simulation tools[22][23]. However, such tools can mainly deal with static or historical data and be used to deliberate design strategies, rather than operational data processing. Research and technical efforts are expected for developing two types of digital tools that can increase the management efficiency of built projects.

### 3.1 Ecological Monitoring Tools

From the authors’ view, it is not difficult to acquire post-operation usage data or image data of built landscape projects. Nevertheless, ecological benefits that designers and owners concerned about the most are hard to monitor or measure. In other words, landscape architects do not lack tools for data screening or mining, but the proactive acquisition about ecological information.

In Urban Planning and Architecture, social media, mobile phone signals, and streetscape images are now the primary data for information management and evaluation. Because these data are relatively easy to collect from smart phones, UAVs, and city cameras[3]. Moreover, image computing, statistical analysis, spatial GIS mapping, and machine learning have formed a new research paradigm in this field. Research on landscape design upon such data sources focuses on 1) city-scale element identification, and semantic segmentation of landscape images[24][25]; 2) training urban streetscape models by machine learning to evaluate urban space

景观设计利用上述数据开展的研究集中于：1）城市尺度的要素识别以及城市景观图像数据的语义分割[24][25]；2）以城市街景及相关评价数据训练机器学习模型，用于城市景观品质评价[26]；3）通过社交媒体数据分析景观设计项目的用户空间使用模式[27]。

但不难发现，上述应用虽能在一定程度上指导项目的运营维护，但大多聚焦于社会绩效的探究。而景观设计项目往往涉及复杂的自然过程，土壤改良、雨洪管理、气候调节等生态绩效也更需要清晰的量化分析，景观设计师亟需从被动的数据挖掘走向主动的数据采集。笔者认为，景观设计项目在生态绩效监测方面遇到了以下三个瓶颈：1）场地中多种调节服务实测数据不足[28]；2）已有实测方法监测周期短、数据精度不高[29]；3）水文调节、小气候调节、污染控制等过程所涉及的核心数据的获取较为分散，缺乏关联耦合研究[30][31]。与此同时，降温、固碳、降噪、抗污染、生物多样性保护等方面的监测方法已在生态学、地理学等学科领域内广泛应用[30]。另外，相较于常见的实验室测度和模型模拟，新技术支持下的、在真实场地内长期开展的实时生态数据监测又能够更直接、有效地指导景观设计项目的绩效评估和项目管理，进而促进设计优化。因此，景观设计师需要具备跨学科的视角，积极掌握获取上述数据的技术手段。

### 3.2 高效的信息模型工具

信息的获取只是信息管理的开端，而构建信息模型是信息分类存储和分析呈现的最有效手段。目前相关学科内的信息模型工具主要包括城市信息模型（CIM）、建筑信息模型（BIM），以及景观设计信息模型（LIM）三大类。其中，LIM利用数字化建模方式描述景观设计对象、对象属性和对象之间的关系，内容涵盖设计、建造及运行各个阶段，辅助制图、管理和优化[32]，常使用文本及图形两种基本形式。LIM用于项目运行场景时，文本等实时更新的数据流②反映项目的动态，而3D图形则作为信息呈现的“基本底图”反映项目的空间形态和信息点位。但目前LIM从设计模型到运行模型的衔接仍有较远的发展距离，缺乏较为开放的LIM技术标准将各类静态或动态信息整合。

目前，景观设计师常用的推敲方案的空间模型包括SketchUp、Rhino等，优势在于操作简便、形态生成能力强、材质渲染表现突出，但其本质仍为封闭式的静态模型，较难导入运行阶段的实时信息；且上

② 数据流由德国计算机科学家莫妮卡·海辛格于1998年提出，指的是一组依次、大量、快速、连续到达的数据序列。一般情况下，数据流可被视为一个随时间延续而无限增长的动态数据集合，目前已被应用于网络监控、传感器网络、航空航天、气象测控和金融服务等领域（参见参考文献[56]）。

quality[26]; and 3) analyzing citizens' usage patterns in landscape projects upon social media data[27].

The above applications can guide the management and maintenance of built projects to a certain extent, and most of them are used to study social performance. However, landscape projects involve complex natural processes, where ecological performance in soil improvement, stormwater management, and micro-climate regulation requires precise quantitative analysis. Therefore, landscape architects need to change their workflow from the mining of given data towards proactive data acquisition. Landscape architects have currently encountered bottlenecks in ecological performance monitoring, including 1) measured data of various regulation ecosystem services of landscape sites are insufficient[28]; 2) existing monitoring often spans a short period of time with a poor data accuracy[29]; and 3) the acquisition of core data in hydrological regulation, micro-climate regulation, and pollution control replies on individual cases and lacks coupling research[30][31]. Simultaneously, in Ecology and Geography, approaches to monitoring urban cooling, carbon fixation, noise reduction, pollution treatment, and biodiversity protection have been well explored[30]. Compared with laboratory experiments and model simulations, long-term and real-time ecological data monitoring assisted by new tools can effectively inform the performance evaluation and management of built projects. Landscape architects are recommended to master the knowledge and technics for such data acquisition with an cross-disciplinary vision.

### 3.2 Information Modeling Tools

Beside data acquisition, information management also leverages information modeling to classify, store, analyze, and visualize data. At present, information modeling tools in related disciplines include city information modeling (CIM), building information modeling (BIM), and landscape information modeling (LIM). LIM is used to describe landscape elements, as well as their attributes and relations in design, construction, and operation stages to assist the mapping, management, and optimization of landscape projects[32]. Text and graphics are two primary formats of LIM: in a LIM for post-operation, real-time data streams② (e.g. texts) can reflect the project's dynamics; and 3D graphics can visualize the project's spatial layout and information points. However, it still requires a lot of efforts for LIM developing from design modeling to operational modeling because of the lack of open LIM technical standards that can integrate various sorts of static and dynamic data.

At present, popular modeling tools for landscape design like SketchUp and Rhino have easy operation system and outstanding shape-generation and rendering capabilities, but, as offline static models, they do not support real-time data import or processing. These tools also show poor multi-platform compatibility for interdisciplinary collaboration, where a single modification in the design can affect the whole workflow that would cause inconvenience to comprehensive management. Although professional BIM platforms (e.g. Revit) can support interdisciplinary collaboration, they are not well promoted because of their closed-

② Data stream is a set of sequential, large, fast, and continuous data sequences, proposed by Monika Henzinger, a German computer scientist, in 1998. Under normal circumstances, it can be regarded as a dynamic data collection that continues to grow indefinitely. Stream data has been applied in network monitoring, sensor networks, aerospace, meteorological measurement, and financial services (Source: Ref. [56]).

述模型的多平台兼容性较差，不适合多专业协同设计，单一修改往往“牵一发而动全身”，不便于操作基础薄弱的运营方进行信息管理。而专业的BIM模型平台（如Revit）虽然解决了多专业协同操作的困境，但也面临着代码开源度、行业推广度和接受度低，与静态模型的实时数据连接路径不畅通（往往需要设计师利用付费图形编程工具联通数据，并需自行建立数据库）等问题。此外，现有BIM模型平台对于景观设计项目中常见的植物、构筑物缺乏对应的数据标准，即景观设计要素所需采集的信息列表尚不明确。

## 4 在线监测辅助项目运行阶段的生态信息收集

### 4.1 IoT在线监测核心优势

在线监测是指利用传感器以自组织或多跳的方式构成WSN，协作感知、采集、处理传输网络覆盖范围内的对象信息。长期、自主的数据流获取是IoT的核心优势，基于IoT的在线监测方法将极大地提高景观设计项目生态数据采集和绩效评估工作的便捷性和准确性，促进学科循证设计的发展。通过持续、稳定、高数据精度（分钟级别）的监测，设计师能够分析复杂的生态调节过程，进而弥补设计阶段数字模拟方式的不足[33]。随着传感器、数据传输单元的廉价化，以及5G基站的全面部署，在线监测方式的部署和维护成本都将大大降低。需要补充说明的是，在当前全球经济增长放缓、传统设计领域趋于饱和、低端产能过剩的激烈竞争背景下，基于监测的循证设计有潜力纳入行业的技术体系并成为景观设计师新的技术优势[8][12][34]。

### 4.2 IoT在线监测相关应用案例

目前，国内外学者已经基于IoT在线监测技术开展了运行信息采集及绩效评估相关工作，且主要集中在生态绩效维度。

在道路景观方面，美国麻省理工学院可感知城市实验室依托“车联网”开展了一项旨在采集城市环境要素信息的项目——“城市扫描仪”[35]。该项目将机动车辆作为传感器搭载平台，采集街景图像及温度、空气质量等环境指标，用于实时描述城市道路的环境质量。另外，东南大学团队基于IoT监测南京市天保街生态路的降雨和调蓄径流量指标，用于量化评估项目的地表径流控制、雨水利用、生境优化、经济效益等方面的综合绩效[36]。

在高密度城市的绿色基础设施建设方面，美国绿色城市策略团队绿色城市方案开发了能够与座椅相结合、可用于吸收空气有害颗粒物及监测和评估城市公共环境的空气质量的“城市绿墙”[37]。美国马里兰大学团队与设备供应商合作，在校园内搭建了16个屋顶绿化实验平台，利用IoT实时监测绿色屋顶的土壤湿度及稳定性，定量收集蒸发量和径流控

source software systems, and the deficient transmission of real-time data with static models (it often requires paid graphic programming tools and to establish database by users on their own). Besides, existing BIM platforms lack clear standards for data collection of common landscape elements (e.g., plants and outdoor structures).

## 4 Ecological Data Acquisition in Post-Operation Stage with Online Monitoring Tools

### 4.1 Advantages of IoT Online Monitoring

Online monitoring is to utilize sensors to form a self-organizing or multi-hop wireless network that coordinates sensing, collecting, and processing target information within the transmission network coverage. Taking IoT's advantage in long-term proactive data acquisition, IoT-based online monitoring will significantly improve the convenience and accuracy of ecological monitoring and performance evaluation for built projects, and eventually promote evidence-based design in Landscape Architecture. Through continuous, stable minute-level data monitoring, designers can analyze complex ecological processes to rectify and iterate design simulation[33]. As the decrease of the cost of sensors and data transfer units (DTU) and the increase of 5G base stations, online monitoring and maintenance will show a sharper cost-effectiveness. Under the fierce competition during the current global economic depression, the market in traditional design industries is becoming glut. Landscape architects need to seize the opportunity to leverage the evidence-based design assisted with monitoring tools as part of the industry's technical system to enhance the profession's competitiveness[8][12][34].

### 4.2 Case Studies on IoT Online Monitoring

At present, scholars have carried out post-operation data collection and performance evaluation with IoT online monitoring tools, mainly on revealing the ecological performance of landscape projects.

In terms of streetscape, the Sensable City Lab from the Massachusetts Institute of Technology utilized the "Internet of Vehicles" to design a "City Scanner" for urban environmental data collection[35]. In this project, motor vehicles serve as mobile sensing agents to collect streetscape images and environmental data such as temperature and air quality, and support the real-time visualization of the overall quality of the monitored urban streets. A team from Southeast University used IoT to monitor precipitation and runoff indicators on the Tianbao Street Ecological Road in Nanjing. This research quantitatively evaluated the street's overall performance regarding surface runoff reduction, rainwater reuse, habitat improvement, and economic benefits[36].

As for green infrastructure in high-density cities, Green City Solutions from the United States has designed CityTree, an innovative seating furniture that can absorb harmful particulates from the air and monitor air quality[37]. A research team from the University of Maryland built 16 green-roof experiment platforms on the campus cooperated with an equipment supplier—Decagon Devices. They used

制量数据[38]。英国布里斯托大学团队在布里斯托市开展了在线水质监测项目“开放布里斯托”，研究者设计了自动采集箱，利用Wi-Fi网络实时采集pH值、电导率、溶解氧、氧化还原电位等关键水质指标，并在项目网页上实时发布当地滨水环境质量监测结果[39]。中国清华大学团队则在胜因院搭建了基于IoT的雨洪管理监测平台，利用多种传感器采集数据，对场地内乔木及雨水花园的降雨径流削减作用进行了可视化[40]。

此外，国内外的诸多企业正积极参与城市绿色基础设施的智能升级，覆盖项目设计、实地安装、后期维护和评估等方面，并已在美国、中国等国家和地区开展了试点项目[41]。

### 4.3 IoT在线监测方法的应用原则

在开展在线监测之时，景观设计师需明确的基本应用方式和原则包括：

1）景观设计项目的尺度多样，根据监测设备的特点并结合已有案例可知，在线监测多面向面积1hm$^2$左右的中微观尺度项目或单个绿色基础设施，更适用于揭示细致的生态过程；更大尺度项目的监测成本较高，宜采用遥感分析结合局部监测的方式。

2）结合可利用的传感设施，优先布局采集结构化的生态数据，如温度、湿度、光照强度、风速、降雨量、水质等；可根据项目的具体监测需求，将数据类型细分为气象条件、空气和水质状况、雨洪调节、土壤健康、植物生长等[42]。

3）传感设备要求稳定、成熟、相对低价，避免“为了智能而智能”“为了监测而监测”。

4）优先布局涉及环境保护及使用安全的关键监测点，满足及时分析、预警、反馈等需求。

5）在线监测涉及诸多指标，因而关键性指标的细化与量化、监测装置的设计，以及监测系统的优化需要景观设计师独立完成。

6）监测指标要具有展示和教育功能，能够帮助市民更好地认识及感知景观设计。

## 5 IoT辅助构建动态景观设计信息模型

### 5.1 IoT与LIM耦合的核心优势

笔者认为，随着数据来源的增多，专属于景观设计场景的数据环境

IoT to monitor the real-time soil moisture and stability of the green roof to inform the evaporation and runoff control[38]. A team from the University of Bristol in UK carried out an online water quality monitoring project called “Bristol Is Open”. The researchers designed an automatic monitoring box and used a Wi-Fi network to collect key indicators (e.g. pH value, conductivity, dissolved oxygen, and oxidation-reduction potential) at the city’s waterfront. Real-time water quality data were updated on the project webpage[39]. In China, a Tsinghua University team has built an IoT-based stormwater management monitoring platform on the campus by using a number of sensors to visualize the runoff reduction by canopy trees and bio-retentions on the site[40].

Besides, many Chinese and foreign enterprises are making efforts in upgrading urban green infrastructure, covering design, on-site installation, post-maintenance, evaluation, etc. Pilot projects have been launched in the United States, China, and other countries[41].

### 4.3 Principles of the Application of IoT Online Monitoring

For landscape architects, the principles of the application of IoT online monitoring include:

1) Considering the characteristics of each sensor and the experience from existing practice cases, online monitoring is suitable for medium-/site-scale projects or individual green infrastructure projects around 1 hm$^2$, and for revealing detailed ecological processes. Since larger-scale projects often cost more in monitoring, remote sensing measures combined with local monitoring should be adopted.

2) Utilize available sensors that can collect structured ecological data, such as temperature, humidity, light intensity, wind speed, precipitation, and water quality. Such data can be further categorized into meteorological conditions, air and water quality, stormwater management, soil health, and plant growth according to different monitoring objectives[42].

3) Sensors should be stable and relatively low-priced, and avoid blind intelligent updates as well.

4) Prioritize monitoring the locations that are key to the environmental protection and public safety, and ensure online analysis, warning, and real-time feedback.

5) Online monitoring involves sorts of indicators, and landscape architects need to refine key ones, design specific monitoring devices, and optimize the sensing system on their own.

And 6) the selection of monitoring indicators needs to be with exhibition and educational considerations, to help citizens better understand and perceive landscape design.

## 5 IoT-Based Dynamic Landscape Information Modeling

### 5.1 Advantages of IoT–LIM integration

With the increase of data sources, the authors believe that exclusive data

将逐步形成，高效的存储、分析和可视化等OIM需求也会接踵而至。简要来说，在线监测更多关注以往被忽略的生态数据的获取，而动态建模则聚焦于系统化的数据组织与呈现。在BIM领域，运行阶段的信息模型动态化是目前工作流中最薄弱的新兴技术环节。

在现有比较成熟的BIM的工作流中，不同的设计师、建模师、结构工程师、造价分析师和施工单位之间基于BIM协同工作，实现了设计建造阶段的高效合作、分析和出图[42]。但BIM的意义远不止于体现“一张图”带来的高效工程设计流程，动态模型能够有效发挥信息模型在项目运营、维护、管理阶段的优势，实现基于运行数据的实时分析、评估、决策。因此，动态信息建模并非只是软件组合的工作流，其核心优势在于信息的实时反馈。现有IoT和BIM耦合技术已经在工业制造、能源设施监测、施工安全及建筑物能耗等场景实现了实时信息反馈和呈现[43]，其方法对于动态LIM构建具有借鉴意义：1）项目后期运行数据的自动化存储和分析可为评估和管理提供依据[44]；2）动态模型结合可视化界面能使管理者直观地发现设计和维护问题、优化设施布局、避免无效和过度设计及资金浪费；3）协助划定责任边界，针对政府投资、PPP等多种开发模式，实现设计、施工、管理阶段的全生命周期按效付费[45]。

### 5.2 IoT与LIM耦合的方式与参考案例

目前，LIM和IoT结合的主流方法有两种：1）利用成熟BIM软件的应用程序端口（Application Programming Interface，简称“API”）进行二次编程，连接模型与实时更新的关系型数据库（图2）；2）使用语义网页技术等混合方法创建新的查询语言和可视化平台（图3）。

作为当前研究及应用最为广泛的结合方法，第一种方式主要是将现有的成熟软件（如Revit、ArcGIS）作为数据库，利用API（如Revit DB Link、Dynamo、Grasshopper）将传感器的数据流②导入LIM平台实时显示。吴正翰等人利用游戏引擎和Revit DB Link建立实时更新校园建筑热消耗的Revit模型[46]。丁凯等人开发了一种钢制桥梁全生命周期的BIM体系框架，基于Revit整合了力学模拟、施工监测、运行维护实时数据等多类动态模型[47]。但是这一方式推广的阻力恰恰来自于软件平台本身：目前，相比于BIM的工业基础分类（Industry Foundation Classes，简称“IFC”）数据标准，国际上尚未形成体系化的LIM数据标准，IFC数据库中景观设计相关指标的信息存储方式尚不清晰。换言之，IFC就是BIM领域的“PDF格式”，提供一个源文件不可以编辑的模型副本在不同软件间进行调用，目前，这个交流格式与景观设计场景的兼容性不佳[48]~[50]。

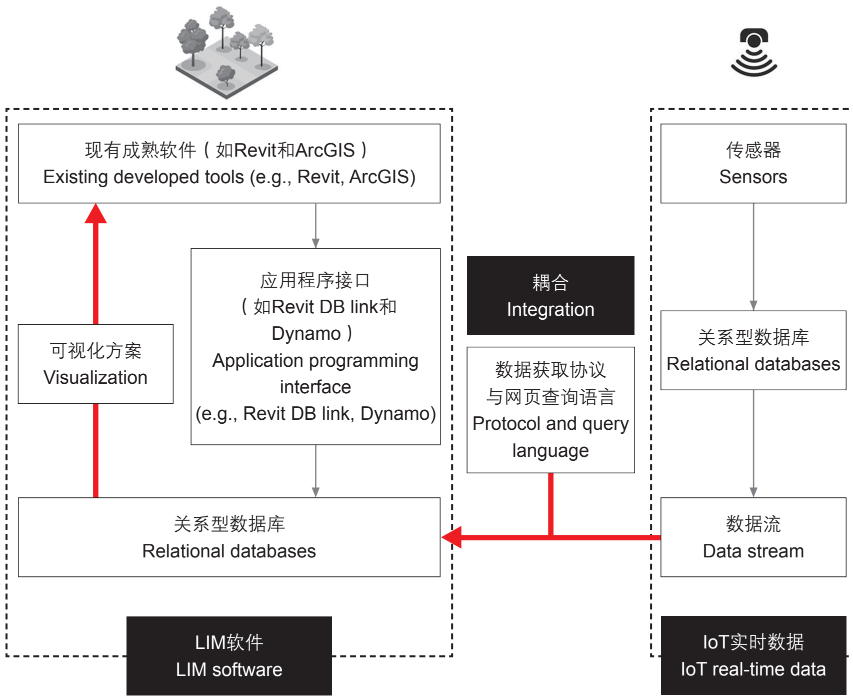
systems for landscape projects will be established to meet new OIM requirements in efficient storage, analysis, and visualization. In short, online monitoring contributes to the neglected acquisition of ecological data, and dynamic modeling can support systematic data organization and presentation. In current BIM workflow, dynamic modeling for post-operation is the weakest but emerging part.

Current BIM workflow allows designers, model engineers, structural engineers, cost analysts, and constructors to work on the same digital platform and work on the same plan, increasing the efficiency of cooperation, analysis, and mapping[42]. Nevertheless, BIM's advantage is far more than that. Dynamic modeling can effectively contribute to the real-time data analysis, evaluation, and decision-making in the operation, maintenance, and management of built projects. This means that dynamic modeling is not simply a multi-software workflow; instead, its superiority lies in real-time feedback. IoT-BIM integration has achieved real-time data feedback and visualization in industrial manufacturing, power supply facility monitoring, construction safety, building energy management, etc.[43], which offers references of dynamic LIM to landscape architects: 1) automatic storage and analysis of post-operation data can inform project evaluation and management[44]; 2) dynamic modeling combined with visualized interfaces facilitates problem-finding in design and maintenance stage, optimizes facility layout, and avoids over-design or gratuitous overhead; and 3) clarify the responsibility and duty of each stakeholder, and particularly for government-funded or PPP projects the payment should depend on the whole life-cycle performance (i.e. design, construction, and management) of the project[45].

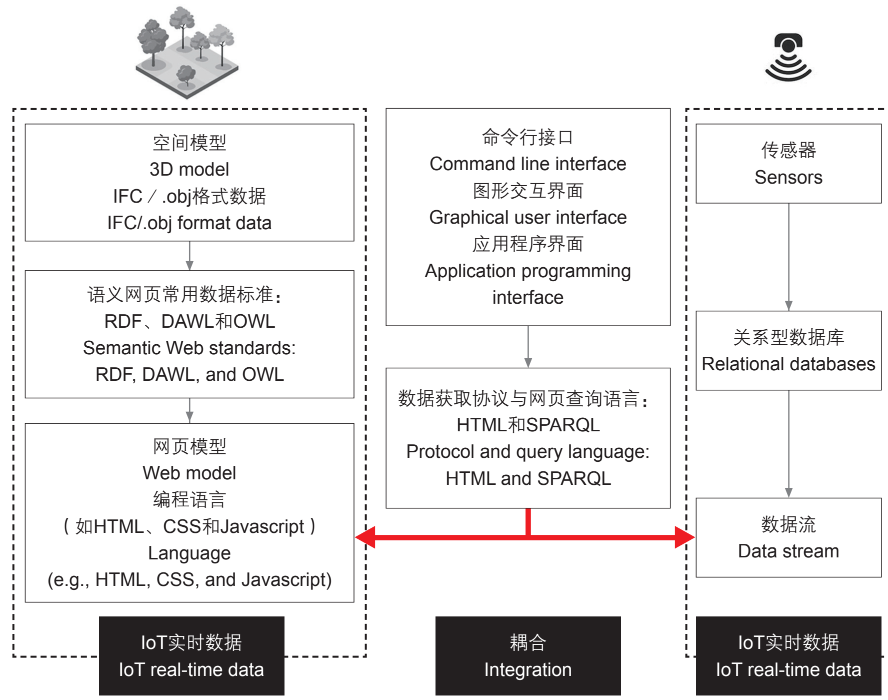
### 5.2 Approaches to IoT-LIM Integration and Case Studies

At present, there are two mainstream approaches to IoT–LIM integration: 1) performing secondary programming through application programming interfaces (API) to connect with existing BIM software and real-time relational databases (Fig. 2); and 2) using hybrid methods like Semantic Web to create new query languages and visualization platforms (Fig. 3).

As the most widely studied and practiced approach, the first one utilizes well-developed software (e.g. Revit, ArcGIS) as the database and operates API (e.g. Revit DB Link, Dynamo, Grasshopper) to import data streams into the LIM platform. With a game-engine and Revit DB Link, Jeong-Han Woo et al. built a virtual campus model that updates the real-time energy benchmarking of buildings[46]. Ding Kai et al. developed a whole life-cycle BIM system for steel bridges using Revit, which can integrate multiple mechanical, construction, and maintenance simulation models[47]. However, this software also have limitations: compared with BIM which follows the Industry Foundation Classes (IFC) standard, there is no systematic LIM standards internationally, and IFC database does not stipulate the data storage method to landscape-related indicators—Like a "PDF format" of BIM, IFC provides an uneditable model copy can be exchanged between different software platforms. However, for now, this format is not compatible with landscape design scenarios[48]~[50].



2



3

第二种方式则为解决这一兼容性问题提供了新的思路：IoT能够支持基于语义网页的LIM网页化，这可减少设计师学习专业软件的时间成本[51]。如在英国卡迪夫大学的实时建筑室内环境监测OntoFM软件开发项目中，工程师将常用的IFC格式转换为Web语言，在Web端建立数据库收集传感器信息，实现模型形态与传感数据在网页端的整合[52]。芬兰阿尔托大学团队则深入探讨了IoT与信息模型耦合的开放标准工作流，并基于Otaniemi 3D的网页模型平台搭建了可实时反映大学校园空间的温湿度、照度、实时人流量的信息的模型（图4）[53]。中国北京智慧甲板团队在北京海淀公园智慧化改造中基于网页、手机应用程序等多种平台搭建具有实时反馈和互动功能的信息模型，在景观设计领域实现IoT与LIM耦合的实际应用[54]。唐舒等人在其高引综述文章中指出，IoT与LIM耦合的未来发展将重点关注服务导向的体系构建与基于Web平台的LIM和IoT集成策略，进而逐步建立新的数据标准[55]。

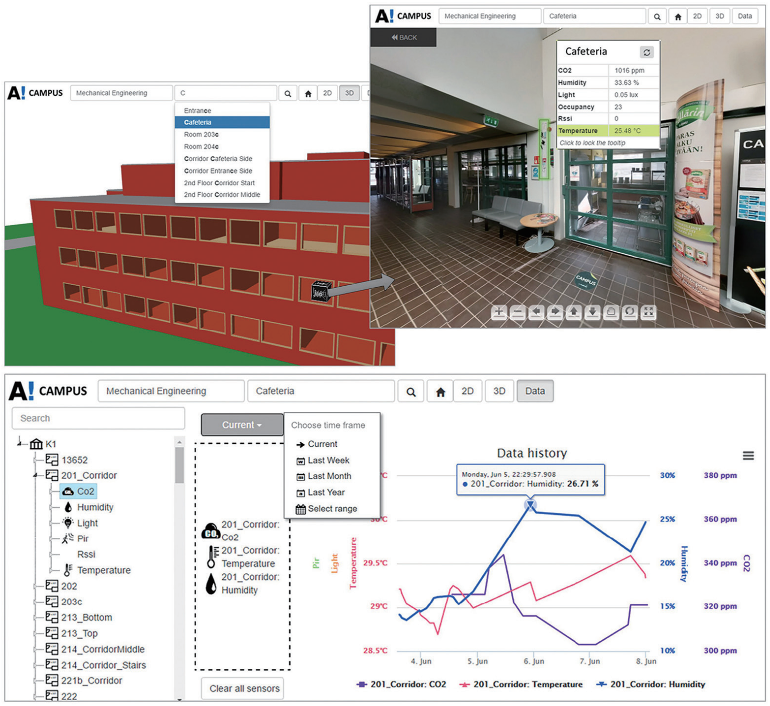
虽然上述动态建模案例集中在小尺度场地，但笔者认为，动态信息模型往往不受项目尺度限制：不难发现，从中国国土空间规划体系“一张图”政策下的大型自然保护地，到城市尺度的公园，再到街边绿地、花园，其规划设计往往都依赖地理信息系统或对应尺度的空间模型。上述景观设计对象的尺度各异，建设或保护的目标也不尽相同，但基于相同工作底图、提升工作效率、减少信息偏差、动态信息可反馈等核心需求是一致的：1）动态的自然保护地LIM往往基于地理信息系统，可实时更新监测数据并完成分析结果的可视化；2）动态的城市公园LIM可基于网页模型，实时更新人流量、水热舒适、雨洪管理、气象条件及污染等信息；3）动态的小型绿色基础设施既可利用现有的Revit软件，也可利用网页模型，结合在线监测开展更细致的绩效评估研究。IoT与LIM耦合相关的场景、目标和方式归纳可见表1。

The second approach provides an alternative idea to solve the incompatibility: IoT can support LIM development on the Semantic Web that can considerably save designers' time to learn to use the software mentioned[51]. For example, in the OntoFM project, Cardiff University in UK researchers converted the IFC format into a web language and achieved real-time indoor environment monitoring. They established a database to store sensors' data and implemented shape-text integration on a website[52]. An Aalto University team from Finland made in-depth exploration on the open-standard workflow of IoT–BIM integration and built a model on Otaniemi 3D's web platform to update the campus' temperature, humidity, illuminance, and traffic flow in real time (Fig. 4)[53]. In China, Beijing Haidian Park has undergone an intelligent transformation by the Smart Deck team who built a model for real-time feedback and interactive activities based on multiple platforms such as web and mobile phone applications, demonstrating the IoT–LIM integration in built landscape projects[54]. In his highly cited review article, Tang Shu et al. pointed out that the future development of IoT–BIM integration needs to focus on service-oriented architecture and web-based modeling to gradually establish new data standards[55].

The above mentioned dynamic modeling cases are site-scale projects. Efforts of such modeling application at more scales are expected. From national reserves (under the One Bluemap Policy of China's National Spatial Planning), urban parks,

2. 基于成熟软件平台的LIM与IoT的耦合
3. 基于Semantic Web的LIM与IoT的耦合

2. IoT–LIM integration based on existing BIM software
3. IoT–LIM integration based on semantic web

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4. 基于Semantic Web的阿尔托大学实时模型（参见参考文献[53]）
4. The real-time model built by the Aalto University team (Source: Ref. [53])

### 5.3 IoT辅助动态LIM的应用原则

相较于在线监测，动态LIM体系对景观设计师来说具有一定挑战，其技术架构的核心是围绕着IoT的多种数据格式的统一与转换，可简要梳理为处理以下数据关系：1）监测设备端的RS-485端口与Modbus传输

to smaller green spaces (e.g., community gardens), all kinds of landscape projects demand GIS or spatial models. Although the scales and planning/design goals of landscape projects vary a lot, they share the exact dynamic modeling requirements: unifying base map, improving work efficiency, minimizing information deviation, and obtaining opportune feedback. Specifically, 1) dynamic LIM for national parks can be established on GIS platforms, updating real-time monitoring data and visualizing spatial analysis; 2) dynamic LIM for urban parks can be developed on web models to update real-time data of foot traffic, hydro-thermal comfort, stormwater management, meteorological condition, and air pollution; and 3) for smaller green infrastructure, software (e.g. Revit) or web models combined with online monitoring can achieve detailed performance evaluation. The application scenarios, goals, and methods of IoT–LIM integration are summarized in Table 1.

### 5.3 Principles of the Application of IoT-based Dynamic LIM

Compared with online monitoring, dynamic LIM poses a bigger challenge for landscape architects in format conversion and standardization. Targeted data types include 1) RS–485 port and Modbus transport protocols of the monitoring device; 2) real-time data processing and storage in relational databases; 3) compatible formats for the 3D mesh of the design model and its materials, such as .obj or .stl format files; 4) IFC formats output by detailed integrated models for structural, water, and electrical engineering design; and 5) XML or other formats that can be responded to on the Semantic Web. Instead of a single software or a fixed standard, dynamic LIM requires a compatible and integrated workflow, where IoT plays a crucial role. Besides, given modeling's convenience and generalizability, landscape architects should choose open-sourced models over commercial software with poor popularity.

**表1：LIM与IoT耦合的景观应用场景、目标及方式**
**Table 1: Application scenarios, goals, and methods of IoT–LIM integration**

| 应用场景<br>Application scenarios | 动态化目标<br>Goals of dynamic modeling | 信息模型平台<br>Platforms | 动态化方式<br>Dynamic modeling methods | 数据指标<br>Monitoring indicators |
|---|---|---|---|---|
| **自然保护地**<br>**Natural reserves** | “一张图”规划信息整合；科学研究<br>Planning Information Unified to One Bluemap; scientific research | ArcGIS | ArcGIS相关API<br>APIs for ArcGIS | 人流量；气象、水文、土壤监测信息；动植物监测信息<br>Foot traffic; meteorological, hydrological, and soil conditions; animal and plant monitoring |
| **城市公园**<br>**Urban parks** | 循证设计；设施维护；科普教育；科学研究<br>Evidence-based design; maintenance; education; scientific research | ArcGIS、Revit、Rhino、SketchUp | Revit相关API（如Revit DB Link、Dynamo、Rhino、Grasshopper）；网页端地理信息系统；网页端OBJ格式模型<br>APIs for Revit (e.g., Revit DB Link, Dynamo, Rhino, Grasshopper); web-based GIS; web-based .obj format model | 气象信息；空气污染物信息；热舒适度；雨洪管理(径流削减量)；人流量；互动设施使用情况<br>Weather; air pollutant; thermal comfort; stormwater management (runoff reduction); foot traffic; interactive facilities |
| **单体绿色基础设施**<br>**Site-scale green infrastructure** | 循证设计；科学研究；设施维护<br>Evidence-based design; scientific research; maintenance | Rhino、SketchUp、Revit | Revit相关API（如Revit DB Link、Dynamo、Rhino、Grasshopper）；网页端地理信息系统；网页端OBJ格式模型<br>APIs for Revit (e.g., Revit DB Link, Dynamo, Rhino, Grasshopper); web-based GIS; web-based .obj format model | 植物生长、土壤状况（温度、含水量）；雨洪管理；微气候调节（温湿度）；热舒适度<br>Plant health and soil condition (temperature and moisture content); stormwater management; micro-climate regulation (temperature and humidity); thermal comfort |

协议；2）实时数据与关系型数据库间的数据监听与存储；3）设计表现模型的三维网格及其材质的兼容格式，例如OBJ或STL文件；4）结构、水、电多专业协同模型端输出的IFC格式文件；5）网页平台端可调用的XML等格式文件。从上述数据关系中不难发现，动态LIM的构建应是一整套工作流程，绝非单个软件或固定标准所能全部完成的，而IoT在其中起到了关键的数据联通作用。此外，鉴于建模的便捷性和可推广性，景观设计师不宜选用普及度差或开源度低的商业软件。

笔者基于上述数据架构初步提出依托网页平台构建动态LIM的景观设计项目工作流程：

1）基于常用的设计软件平台（如Rhino或开源软件Blender）搭建监测场地的空间模型，保留材质输出为OBJ格式；

2）基于WebGL等平台布局网页端信息模型的文本及图形框架，利用Python、Html、JavaScript、CSS等编程语言设计网页版式，并调用Python Dash库用于数据的可视化，进一步编写分析算法将OBJ模型内置到Web；

3）搭建项目的专用服务器，申请审核可用的域名，并编写后台管理程序；

4）基于常用的数据库平台MySQL在服务器端搭建关系型数据库用于实时数据的存储；

5）连接网页模型与关系型数据库，设置网页自动更新频率即可与在线监测的数据实现同步连接。

## 6 结语

本文围绕实时性、高精度、便捷性、长周期、低人力等IoT技术的核心优势，着重关注景观设计项目运行阶段数字工具的空缺与需求，通过案例分析和文献综述总结出IoT与项目OIM结合的两大应用路径：

1）IoT在线监测辅助生态数据获取。目前成熟的应用案例主要集中在气候调节、雨洪管理、污染治理等指标的实时收集。相关案例中，景观设计师结合项目的生态目标，部署可结构化采集的传感器，利用5G或Nb-IoT等新型传输形式，实现了高精度的数据采集。

2）IoT辅助构建动态LIM。搭建高质量的信息模型并与IoT监测数据库对应，基于语义网页等多平台开发自动化分析、可视化程序包。模型中常以文本形式存储结构化采集的相关指标；以图形形式表达监测场地的3D模型（作为数据可视化的底图）；数据可视化算法辅助呈现累积图、关联图、热力图和分布图等分析结果。

在探讨IoT与景观设计研究的结合时，我们不仅要关注IoT技术的研究动向，更重要的是要明确学科本身的实践需求，以避免设计师和项目管理者落入“为了应用而应用”的陷阱。而面对学科研究的未来时，本文试图揭示一种行业技术升级引发需求升级的发展过程，这一升级也将带来景观设计领域的诸多变革：

1）景观设计师的定位转变。在智慧城市建设中，景观将不仅实现城市空间提升，更将成为“城市大脑”的一部分，这要求景观设计师走出学科传统空间设计的舒适区。未来智慧景观系统不仅包含自然要素，

The authors propose a primary procedure of dynamic LIM for landscape architects based on the Semantic Web:

1) Build a spatial model of the monitoring site with commonly used design software (e.g., Rhinos, Blender), and output .obj format files;

2) Layout the text and graphical content using platforms such as WebGL, design and program the webpage with Python, Html, JavaScript, or CSS, invoke the Python Dash Datacamp for data visualization, and integrate analysis algorithms with the .obj format model;

3) Set up a cloud server for the project, apply for available domain names, and program background administrational algorithms;

4) Establish a relational database on the cloud server using MySQL for data storage;

And 5) link the webpage to the relational database, and set the frequency of automatic updates to synchronize the real-time data.

## 6 Conclusions

This article summarizes IoT's superiority in supporting real-time, high-precision, convenient, long-term, and low-cost modeling. Through case studies and literature review, it highlights the vacancies and requirements of OIM tools for built landscape projects from the following two aspects:

1) The acquisition of ecological data assisted with IoT online monitoring. Current practice often integrates IoT and landscape scenarios to collect real-time data of climate regulation, stormwater management, and pollution remediation. In these cases, landscape architects deploy sensors to acquire high-accuracy data of the project's ecological performance with new networks such as 5G and Nb–IoT.

And 2) IoT-based dynamic LIM. By building a high-quality information model linked with IoT monitoring database, automatic analysis and visualization packages can be developed with multiple platforms (Semantic Web). The model stores indicators collected as structured text; the 3D representation of the monitoring site is in a graphical form (as a base map for data visualization); and visualization algorithms present the analysis results as cumulative graphs, correlation graphs, heat maps, or distribution graphs.

To integrate IoT with design research, landscape architects should pay attention to emerging research trends of IoT technology, and more importantly, emphasize authentic application scenarios to avoid blind practice. As for the future of Landscape Architecture, this article attempts to reveal the profession development trajectory that technological upgrade leads to demand upgrade. In the authors' opinion, this integration will also bring about many changes in landscape industry:

1) Landscape architects' contemporary mission changes. In smart city construction, landscape projects are expected to improve urban spatial quality while serving as part of "the city's brain," which requires landscape architects to change mindset and respond to new profession demands. The future smart landscape system includes not only natural elements but also artificial sensing facilities; and

也包含人工传感设施，设计内容将拓宽至系统设计、传感器布局设计及传感装置设计。

2）景观设计和研究工具的革新。IoT为景观设计研究提供了传感器、无线网络、数据平台等多种量化工具；WSN工具获取数据更为便捷、获取周期更长、数据质量更高、数据的应用形式更为多样。

3）景观设计师培养模式的转变。IoT时代，人才培养需要打破专业局限，积极以跨学科的视角去理解IoT的相关新知识。在此过程中，景观设计师无需掌握LIM软件开发，只需了解标准数据格式的转换，并采用开发迭代迅速的网页平台即可较快地实现数据的实时分析与展示。**LAF**

the design work will expand to sensing system design, sensor arrangement, and sensing device design.

2) Innovations of landscape design and research tools. IoT will innovate landscape design and research approaches by providing quantitative tools such as sensors, wireless networks, and data platforms; and WSN tools can support real-time data acquisition of a higher efficiency, a longer collecting span, and a higher data quality, for a greater variety of data application.

3) New methods for talent training. Today, it asks landscape architects to break professional barriers to learn and adopt IoT knowledge in an interdisciplinary way—Landscape architects do not need to develop LIM software on their own, but be familiar with the conversion standard of data formats and utilize web platforms with a rapid iteration rate to realize real-time data analysis and visualization. **LAF**

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