LOD 350 级别的 BIM 模型在土建施工图设计中的作用

杨天伦[1]　乔治斯·卡普吉安尼斯[1]　姜炳圭[1]　罗宾·威尔逊[2]

(1. 宁波诺丁汉大学,宁波　315040; 2. 英国诺丁汉大学,诺丁汉,英国　NG7 2RD)

【摘　要】为了使土建工程的施工图设计阶段在各设计专业间能有更好的协调并且提高施工图设计文件的交付质量,本文调查研究了土建施工图设计阶段在项目管理上的一些问题和因素,归纳总结了 LOD(Level of Development) 350 细度的特征和属性,对 LOD 350 在 BIM 应用中的作用进行分析,通过场景案例来讨论 LOD 350 作用于土建施工图设计管理中的具体方式,并且评估 LOD 350 对提高土建施工图设计文件交付质量的有效性。

【关键词】土建施工图设计;建筑信息模型;LOD 350

【中图分类号】TU17　【文献标识码】A

引言 Introduction

In the design stage of a building project, poor coordination among different design disciplines is a common problem[1]. Poor design coordination will generate many issues, not only delay the design delivery, but also cause problems during the review and construction stage[2]. Repetitive modification (via contact forms) will occur during the construction process, causing unnecessary waste thus to delay the project delivery[3]. Building design is a complicated progress because the successful delivery heavily depends on efficient collaboration among each discipline[4]. Building design close-out only if the construction passes all inspection and deliver to user according to relevant domestic regulations[5]. The design management is important during design stage to ensure the successful coordination of each discipline and sharing of project information[6].

在土建工程的设计阶段,各设计协调不充分的协调是一个常见的问题[1]。设计中协调不充分的协调会产生不良的结果,这不仅会延迟设计图纸的交付,并且会导致项目在审查和施工阶段出现问题[2]。设计交付质量的不足会使设计单位在施工过程中多次出具联系单对施工图进行修改,这将使设计团队产生不必要的资源浪费并且可能导致项目的延迟竣工与交付[3]。土建工程设计是一项庞大并且复杂的过程,顺利的设计交付在很大因素上取决于各设计专业良好的协同合作[4]。根据国内的有关规定,土建设计要跟踪服务到项目竣工并验收通过之后才算完成[5]。为确保各设计专业有良好的协同合作和更好的信息共享,设计管理在土建设计中有着重要的作用[6]。

Building Information Modelling (BIM) is becoming popular in Architecture Engineering and Construction (AEC) industry in recent years because it can increase the information coordination in architecture and infrastructure projects[7]. Design teams can improve their delivery performance in the case of all the building elements are well spatially optimized[8]. During the

【作者简介】　杨天伦(1991 -),男,宁波诺丁汉大学建筑与建筑环境系在读博士研究生,主要研究方向:BIM 模型精度与设计协同合作;乔治斯·卡普吉安尼斯(Georgios Kapogiannis)(1981 -),男,博士,宁波诺丁汉大学建筑信息模型(BIM)助理教授,博士研究生导师,主要研究方向:增强数字化转型与协同合作。

implementation of BIM, the models' detail level play important role[9]. Domestic BIM standard < Standard for Design Delivery of Building Information Modelling > raise the concept of "Level of Model Definition", and divide the model into four levels, which regulates the required information for each level[10]. American Institute of Architect (AIA) divides BIM model into five levels from 100 to 400[11]. These two standards both abbreviate the concept into LOD, which have similar function. LOD guides the implementation of BIM during different stages[12]. The implementation of BIM in design stage requires a clear information guidance to support the decision makings and assessments of design team regarding to the project[13]. Through the analysis and comparison of two standards, this paper consider AIA LOD 350 could effectively fill the gap between LOD 3.0 (components level) and LOD 4.0 (parts level) of the domestic standard in China. Therefore, this paper discusses and assess whether LOD 350 can effectively enhance design coordination, thus, to improve the design qualities in China.

建筑信息模型(BIM)近年来在建筑、工程和施工(AEC)企业中得到了广泛的应用,因为 BIM 可以有效增加土建和基建项目中信息生产和管理的协同合作[7]。土建设计团队的设计交付能力将随着各专业构件在空间上的优化而提高[8]。在 BIM 的执行过程中,模型的精细程度起到了重要的作用[9]。国内 BIM 标准《建筑信息模型设计交付标准》中提出了“模型精细度(Level of Model Definition)”的概念,并且将其划分为四个等级,每个等级对模型所需涵盖的基本单元做了规定[10]。美国建筑师协会(AIA)在 BIM Forum 中提出了“模型发展程度(Level of Development)”的概念,并对其从 100 到 400 进行了五个等级的划分[11]。这两个标准中把这个概念均简称 LOD,对模型精度的划分有着异曲同工的作用。LOD 为 BIM 在土建工程在不同阶段的实施提供了相应的模型参照标准[12]。在土建工程的设计阶段,BIM 执行的关键是需要为设计团队提供相应级别的模型细节来对项目的设计进行决策与评估[13]。经过对两个模型精度标准的对比分析与研究,本文认为 AIA 标准的 LOD 350 能有效填补国内标准中 LOD 3.0(构件级)与 LOD 4.0(零件级)模型单元之间的空白,所以,本文对 LOD 350 在国内设计单位中的应用是否能提高各设计专业之间的信息协调能力与是否能提高设计交付的质量进行了讨论和分析。

1 研究目标、对象和方法 Research Aim, Objects and Methodologies

The aim of this research is to understand whether and how LOD 350 can improve design coordination and thus to improve the design quality. The research objectives of this paper are a) identify the problems and issues in building design management during construction drawing phase b) define properties and characteristic of LOD 350 and c) understand the interrelationships between LOD 350 and design coordination within Chinese Industry.

本文的研究目标为明确 LOD 350 是否能通过提高施工图设计各专业之间的协调来提高设计交付的质量,并且认识这个过程是如何实现的。本文的研究对象为:a)确定在施工图设计阶段的管理中有哪些不良的因素;b)定义 LOD 350 的属性和特征;c)理解在国内设计单位中,LOD 350 与设计协调之间的关联。

Researchers are using mixed method approach aiming to get a more objective approach of people's opinion. Methodologically researchers follow a case study approach and using mixed method (observation and semi structured interviews). Researchers worked on a small residential project that is based in Ningbo, China. Interview participants are from a design company which has Class A building design license and a construction supervision company which has Class A building construction supervision license. Researchers analysed the relation between different disciplines in construction documents design phase. Ethics clearance was provided by the University of Nottingham Ningbo China before the research starts.

本研究采用混合方法来更加客观地从被采访人员的观点中获得研究数据,同时,研究通过混合方法来对一个案例进行研究(观测和半结构式的访谈)。本研究的案例是一个位于浙江省宁波市的小型住宅项目;本研究通过采访一所建筑工程甲级资质设计单位的设计人员和一所房屋建筑工程甲级

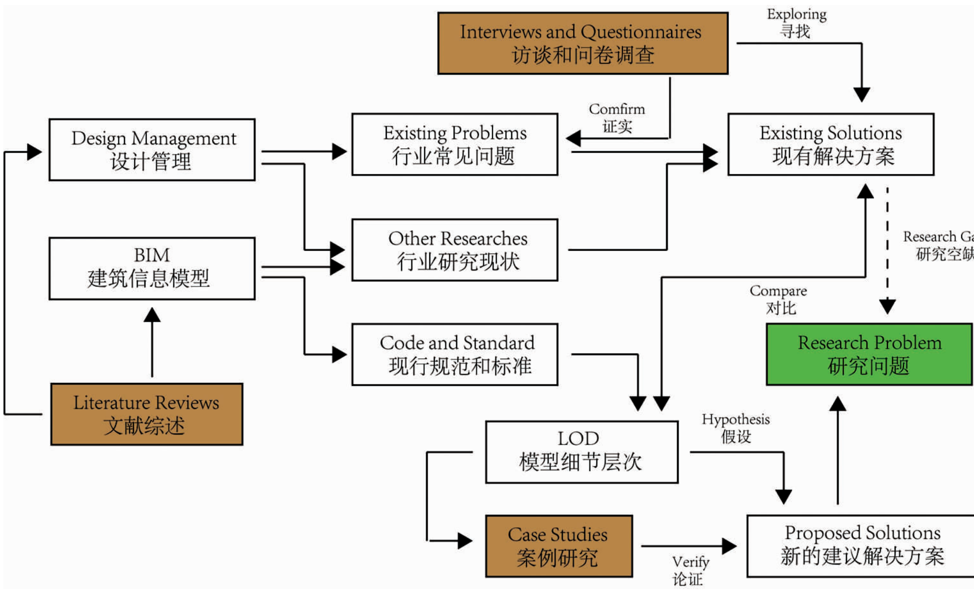

图 1　研究方法

Fig. 1　Research Methodology

资质监理单位的监理人员来分析不同专业在施工图设计阶段的关联。宁波诺丁汉大学在研究开始前通过了对此次研究伦理道德的审查。

For the first research objective, the researchers use literature review to investigate those existing issues in building design, to find those factors that cause poor design management. Moreover, for the second research objective, researchers use semi structured interviews and case scenario to understand certain challenges during the design documents coordination following by observations from the experiment. Findings compared to comprehensive literature review in LOD based on up-to-date standards, analysed the impact of LOD 350 in construction drawing design phase. Finally, the third objective aims to understand the impact of LOD 350 in a scenario and presenting its findings in terms of "how LOD 350 could help to improve document coordination during the design stage of a project".

针对第一个研究对象,研究人员采取文献综述对现阶段的设计问题进行了全面的调查,找出导致不良设计管理的因素。此外,针对第二个研究对象,研究人员采用半结构式访谈和场景案例来理解设计文件协调中的难点,随后对实验进行了观测。本文将研究结果与基于业内最新标准和规范的 LOD 350 特征进行对比,分析了 LOD 350 在施工图设计阶段的作用。最后,第三个研究对象为理解 LOD 350 在一个场景中的作用,并且通过“在项目设计阶段 LOD 350 将如何帮助提高设计文件的协调”的方式来展示研究的结果。

2　施工图文件在设计管理中的问题 Issues of Construction Documents in Design Management

The quality of design documents delivery is important in building project because poor design coordination will delay the construction progress[14]. The traditional building design tools and methods effects the efficiency of this discipline, compare with the history along the century of building design, the current of design delivery is still based on two dimensional sheets[2]. Two dimensional sheets have limitations in spatial coordination, which will affect the evaluation of design team regarding to the potential design problems[15]. Despite the widely adoption of many three-dimensional design tools such as SketchUp and Revit, they are merely adopted in initial design phase, however not deep into construction documents design phase[16]. Many domestic design companies are lack of widely adopt those useful three-dimensional tools to integrate all design disciplines to improve design efficiencies and qualities[17]. Building projects require coordination from multiple disciplines across different stages[18]. These stages consist geological survey, design, and construction (Figure 2). According to domestic regulations, design companies shall respond to relevant questions from construction company during construction stage (via contract forms). Therefore, poor design quality will cause design team to spend extra time making design modifications during construction process. However, ISO 19650 was introduced as a standard to optimise information modelling process in construction projects[19]. In China, this standard is getting attention but not been widely adopted.

设计文件交付的质量是整个建设工程的关键,因为未充分协调的设计文件会影响施工的进程[14]。土建设计工具与方法的传统性极大限制了这个行业的效率,对比建筑设计行业几个世纪以来的历史,现阶段土建项目对于设计的交付仍然停留在二维的图纸上[2]。二维的设计图纸在空间优化与协调上具有相当程度的局限性,这将影响了设计团队对潜在的设计问题进行评估[15]。尽管近年来许多三维设计软件比如 SketchUp 与 Revit 在设计单位得到了广泛应用,但是这些使用仅仅停留在初步阶段,并没有对施工图设计阶段进行深入的优化[16]。国内的许多设计单位缺乏广泛采用对各设计专业具备有效信息协调作用的三维工具来提高土建设计的效率与质量[17]。土建项目在每个阶段均需要各个专业的配合[18]。这些阶段重点包括勘查、设计与施工(图 2)。根据国内的相关法规,在项目施工的过程中设计单位需要对施工单位所提出的相关问题进行书面答复(出具联系单)。所以,设计交付质量的不足将会导致设计单位在施工阶段耗费大量的精力对设计进行调整。ISO 19650 的提出为建设工程信息建模的过程提供了一个标准[19]。在中国,这个标准已经得到重视但未进行广泛采用。

Construction documents design provides details to constructions stage[20]. Construction drawings design demand the collaboration of multiple disciplines, including but not restrict to architecture, structure, and MEP/HVAC (Figure 3). During the construction documents design, lack of communication among different disciplines is a common problem[21]. Because the frequency of design modification, if the modified information cannot be delivered to relevant discipline timely, it will cause the information delay and modification delay, thus lead to the poor coordination in the end[22]. The limitation of communication tools among design team is another problem that cause poor communication during the design process[23] Following the lack of collaborative culture, the performance of construction project will be affected thus likely will end up with failure[24]. In domestic design companies, it lacks to widely adopt Common Data Environment (CDE) platforms; those common instant communication tools are not able to effectively provide storage and share documents (regarding to the historic version of design documents and are not able to provide effectively feedback - design review and references)[25]. In domestic building design companies, architecture is the leading discipline to coordinate and review the designs. Meanwhile, as being considered as core disciplines, the coordination between architecture and structure is important to ensure the spatial reasonability[26]. The MEP disciplines provide building equipment design based on architecture and structural design. These designs are integrated in order using relevant tools[8] (e. g. Navisworks clashes must be reported).

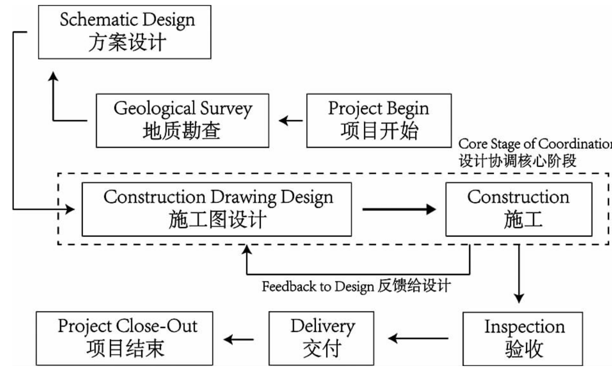

图 2　项目交付流程

Fig. 2　Project Delivery Process

施工图设计的主要目的是为施工阶段提供了相应的构造与细节做法[20]。施工图设计需要多专业的协同合作,这些专业包括但不局限于建筑、结构和机电(图 3)。在施工图的设计中,各专业缺乏在设计内容与信息上的有效交流是一个常见的问题[21]。由于在设计过程中设计变更的频繁,变更信息如果无法及时传递给相关专业,将会产生信息的

滞后和设计修改的不及时，最后导致在各专业设计图纸汇总后发现在空间上的不协调[22]。各设计专业之间交流工具的局限性也是导致在设计过程中缺乏有效交流的原因之一[23]。在一个缺乏协同合作的环境下，建设项目的绩效会受到影响，并且有可能会导致一个失败的结局[24]。在国内的设计单位中，缺乏广泛采用公共数据环境（CDE）平台；常用的即时通讯工具不能有效地对历史版本的设计文件进行储存与共享，并且不能使设计团队对设计文件进行有效的反馈（设计审查和参考）[25]。在国内的设计单位中，建筑专业通常作为设计总负责来对各专业的图纸进行汇总并审阅。同时，作为项目设计的主要专业，建筑和结构设计之间需要进行充分的协调，以确保项目在空间上的合理性[26]。机电专业基于建筑与结构的设计为项目提供设备的设计。这些专业之间需要通过一些工具来进行整合[8]（比如通过 Navisworks 来进行碰撞检测）。

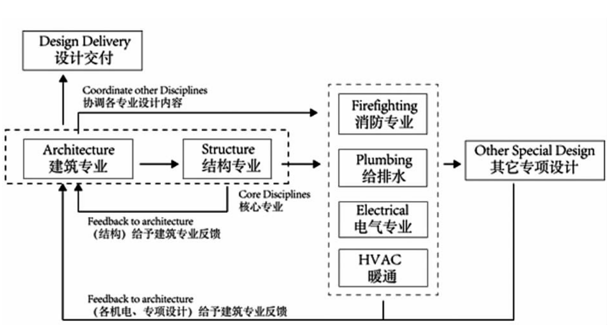

图 3　专业之间的协调

Fig. 3　Coordination Between Disciplines

During the construction drawing design phase, each discipline needs to make changes should comply with schematic design and relevant standards[27]. The lack of pre-identifying potential construction problems during the construction design phase is one of the reasons that cause the delay of the building project[28]. Design team does not make design based on the real construction process and does not make spatial simulations. This result to design inadequacies[29]. The design team uses inefficient communication methods and irrelevant reference information can seriously affect the design efficiencies[30]. The delivery of design can be considered as information delivery (Figure 4). It requires the use of effective reference standard system, mutually agreed, during information production to ensure the information quality and validity[3]. As a result the information production and its quality depends heavily also on the efficiency of information coordination, and in particular to be reviewed by the right person[4]. On this basis researchers run semi structured interviews to seek those challenges (architecture and structure disciplines) based on documents coordination. The output of this research is to meet requirements of the second objective.

在施工图设计阶段，各专业需要依据所定方案和相关规范来开展设计[27]。施工图设计未考虑实际建造中的问题是导致项目延迟交付的原因之一[28]。设计人员未从实际角度出发，缺乏对建筑构件在空间上的模拟与协调将会降低设计的质量[29]。同时各专业设计人员在设计过程中采用低效的沟通方法和使用不充分参考信息会降低设计的效率[30]。工程设计的交付可以被认为是一种信息的交付（图 4）。在信息的生产中需要采取相互认可的，并且有效的参考标准来确保信息的质量与正确性[3]。作为结果，研究信息的生产和其质量同样极大程度上依赖信息协调的效率，并且尤其需要通过合适的人来进行审阅[4]。基于这个理论，作为案例研究的一部分，本研究采取了半结构式的访谈来从设计团队（建筑和结构专业）中寻找施工图设计文件协调的难点。访谈的研究结果是针对第二个研究对象所需要的要求。

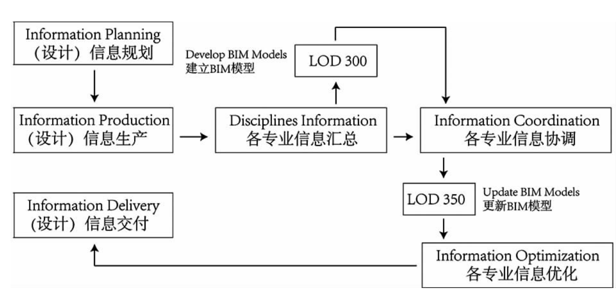

图 4　信息协调过程

Fig. 4　Process of Information Coordination

For the interview in architecture discipline, the research focuses on how it should provide useful information to other disciplines, and how to coordinate with other disciplines through effective communication. For the interviews on structure discipline, this research focuses on how structure discipline needs to coordinate with architecture discipline to achieve design objectives. For the interview on construction supervision discipline, the research focuses on which types of issues in construction documents will impact to the construction progress, and to investigate how design team and construction supervision teams need to coordinate in order to improve the delivery efficiency. Researchers used Nvivo Software to analyse qualitative data by using content analysis method[31]. Based on content analysis, through coding of nodes in Nvivo, researchers tried to map the relationships between the nodes. The key nodes among others are: communication, cooperation, design, construction, information, management, space, etc. Through cluster analysis, Nvivo generated the following diagram (Figure 5) by showing the core challenges in documents coordination in design and construction phase.

在针对建筑专业的研究中,访谈着重调查在设计的过程中,建筑专业应该如何向其它专业提供有效信息并且应该如何与其它专业进行高效的沟通与协调。在针对结构专业的研究中,访谈着重调查结构专业应该如何与建筑专业进行有效配合来实现与完成设计任务。在针对监理专业的调查中,访谈专注于哪些施工图上的问题会影响施工的过程,并且着重于调查建筑和监理专业应该如何协调来提高项目交付的效率。研究人员采用 Nvivo 软件通过内容分析的方法对所收集的定性数据进行分析[31]。基于内容分析,通过在 Nvivo 里对关键节点的编码,研究人员尝试对节点建立关联图。关键节点包括:沟通、协作、设计、施工、信息、管理、空间等。Nvivo 根据聚类分析,生成如图 5 所示来展示设计和施工阶段在设计文件协调上的难点。

According to data analysis results, design will correlate with construction through communication based on the semi structured interviews with construction supervision team. In addition, findings show as a common problem that sheets from different disciplines do not match or compliment with each other. The data in (Figure 5) shows design and construction documents need to be linked through coordination. In addition, findings shown that the feedback comes to building design rather than points out those construction difficulties. Furthermore, findings shown belated design

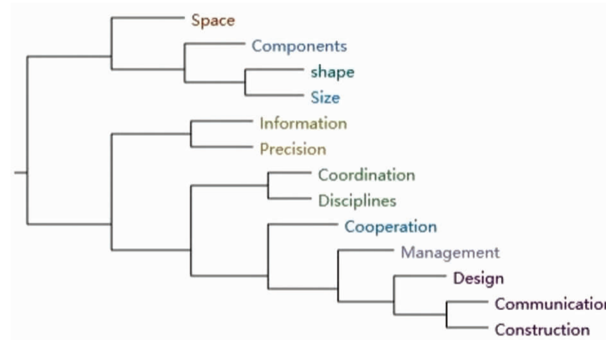

图 5 Nvivo 分析结果

Fig. 5 Nvivo Analysis Result

modification is one of the factors that impact construction. In addition, the Figure 5 shows the coordination of information is related to the precision of information. Also, findings shown from structure discipline lack of clear data in size and shape could cause clashes during the data/information integration as well as challenges with spatial coordination. Therefore, there is a need to model more details to get more a better understanding of potential clashes. These must be discussed with other disciplines to ensure information consistency and high level of quality (note: information is produced in LOD 350 aim to be better enhanced by LOD 400 that will be ready for construction purposes). With the implementation of BIM, design team can visualize more problems[32]. As a result, LOD 350, as an addition element to LOD 300 or LOD 3.0 standard to optimize construction documents design (Figure 6). Also, LOD 350 could be advantageous to be incorporated to secure optimised project communication.

Nvivo 根据对监理专业的半结构式访谈数据分析结果显示,设计(Design)通过沟通(Communication)的方式与施工(Construction)建立关联。另外,数据表明,现阶段各专业的设计图纸在汇总后会产生不一致或相互不能匹配是一个常见的问题。根据图 5 的数据表明,设计(Design)和施工(Construction)与协调(Coordination)具有关联性。同时数据表明,许多反馈仅针对设计的问题而非指出在施工上的难点。此外,研究结果表明,不及时的设计变更也是影响施工的因素之一。而且,图 5 的数据表明,信息的协同合作(Coordination)和信息的精度(Precision)相关联。根据对结构专业的访谈数据中

发现,各构件位置与尺寸信息缺失的将会导致在设计整合中发生空间上的碰撞。所以,需要通过建立更加详细的 BIM 模型来获得对项目设计在空间上潜在的碰撞进行更加透彻的了解。这需要通过与其它专业的讨论与沟通来确保信息的一致性和信息的高质量(注意,在 LOD 350 阶段所生产的信息是为了能在 LOD 400 阶段被更好地优化,来为施工过程提供信息参考)。BIM 的应用可以使设计团队更好地对项目进行可视化,通过检测和分析发现空间设计上的问题[32]。研究结果显示,LOD 350 作为 LOD 300 或者 LOD 3.0 标准的附加元素,可以为施工图设计文件做出优化调整(图6)。同时,LOD 350 可以为项目优化的交流做出有效保障。

Considering therefore findings from the literature review and research outputs, it is evident the need to utilise LOD 350 in the design stage of construction drawings development to eliminate communication risks. However, this requires appropriate information reference system; the use of ISO 19650 could be sufficiently enough to elaborate this challenge[19]. As a result, efficient document coordination through clash detection in early stage could support the development of LOD 400 accordingly. The adoption of this level needs to base on LOD 300 because LOD is a progress development[11]. Next section will analyse the difference between LOD 300 and LOD 350, evaluated the role of each level in design stage.

综合考虑文献综述和半结构式访谈的研究结果,LOD 350 被证实在施工图设计阶段能够有效降低设计团队在交流上存在差错的风险。但是,这个需要拥有合适的信息参考系统,采取 ISO 19650 能够有效应对来自这方面的挑战[19]。所以,在设计阶段通过冲突检测的方式对设计文件进行及时协调能够有效支持 LOD 400 阶段 BIM 模型的建立。采取这个级别的 BIM 模型需要基于 LOD 300 的基础上,因为 LOD 的建立是一个累加的过程[11]。下一章节分析了 LOD 300 和 LOD 350 的区别,并且评估了两者在土建设计阶段的作用。

3 LOD 350 精度的特征研究 Features of LOD 350

Level of Development (LOD) 350 based on AIA standard is introduced on BIM Forum in 2013[33]. LOD 350 is defined between LOD 300 and LOD 400, which models the actual shape and size of building components and make the connection joints in between, aims to improve design optimization before making construction model[11]. Different phases in design stage demand different information level to support decision making and evaluation process[34]. < Standard for Design Delivery of Building Information Modelling > has regulated the delivery accuracy[10]. But this standard was released in December of 2018 and implemented in June of 2019, so before that, the implementation of BIM is normally reference on AIA LOD standard. In domestic construction documents design phase, LOD 300 (equal to domestic standard LOD 3.0 parts level) are mostly being adopted during the BIM imple-

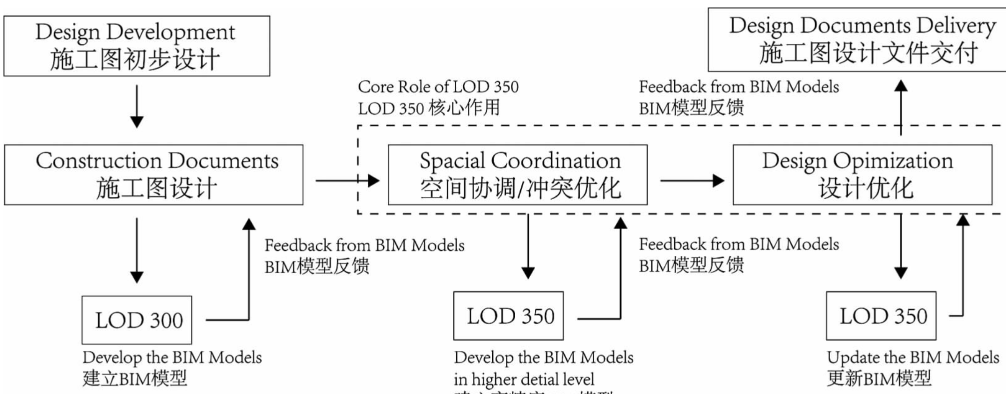

图 6 LOD 350 在设计阶段

Fig. 6 LOD 350 in Design Stage

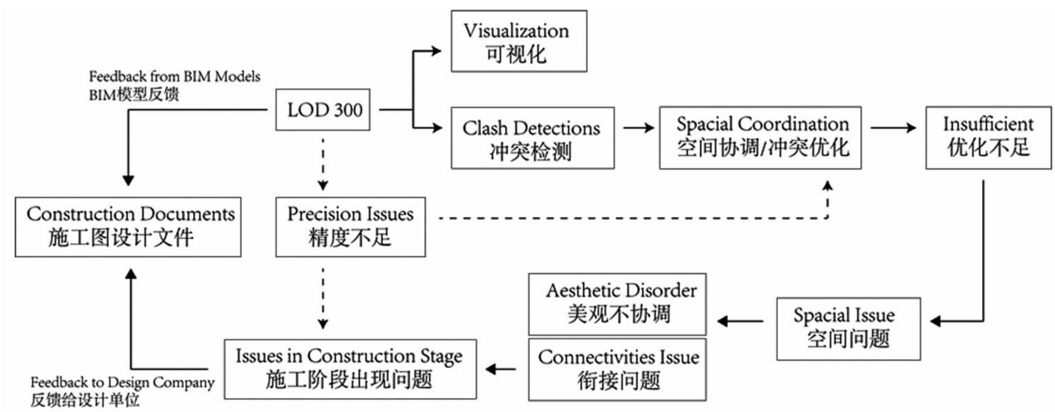

图 7　空间协调不足

Fig. 7　Insufficient Spatial Coordination

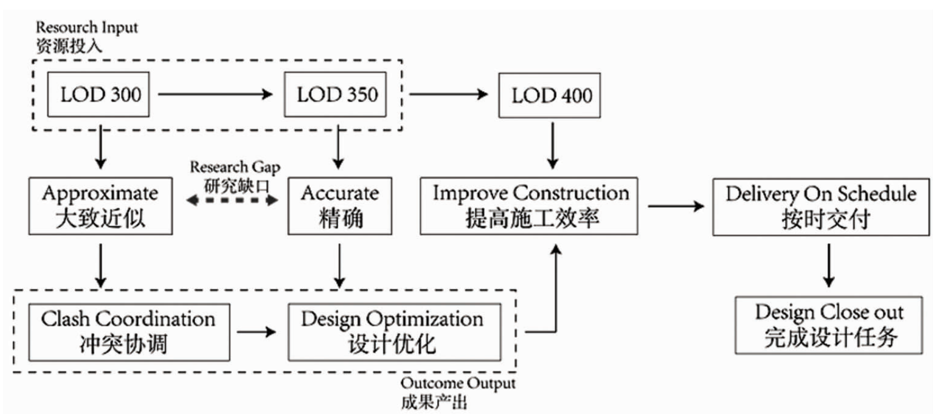

图 8　LOD 350 投入和产出

Fig. 8　Input and Output of LOD 350

mentation. Due to the limitation of LOD 300, spatial coordination at this level might not be enough, therefore, it still will cause multiple problems during construction process (Figure 7).

美国建筑师协会(AIA)标准的 LOD 350 首次于 2013 年在 BIM Forum 上提出[33]。LOD 350 被定义在 LOD 300 与 LOD 400 之间,其要求是对项目各构件进行真实外型与尺寸的建模,并且在各构件之间要求建立连接件,这对建立 BIM 施工模型前的优化起到了过渡的作用[11]。在项目设计的不同阶段需要不同级别的信息细节来为设计评估与决策的过程提供参考信息[34]。《建筑信息模型设计交付标准》中对 BIM 模型精度的交付标准做出了规定[10]。这个标准于 2018 年 12 月推出,并且于 2019 年 6 月正式实施,在此之前,BIM 执行计划通常参考 AIA 的 LOD 标准。在国内施工图设计阶段的 BIM 应用中,最常用的是 LOD 300 级别,等同于现行国内标准的 LOD 3.0(构件级)。由于 LOD 300 在建模深度上的局限性,这个级别的 BIM 模型并不能发现许多空间协调上潜在的不足,所以导致在施工的过程中仍然会出现许多构件碰撞的问题(图 7)。

During BIM implementation, build models at AIA LOD 400 or domestic standard LOD 4.0 (parts level) require input with large amount of workload because this level contains construction details[11]. If design stage is not well coordinated, efforts will be spent to make modifications in LOD 400 or LOD 4.0, which will cause unnecessary resource waste. So, the principle of BIM paradigm can be considered and thus no lean management is applied[35]. Despite develop LOD 350 require inputting certain resource, it will improve design optimization based on LOD 300, which can reduce modification in later stage (Figure 8).

在 BIM 的执行过程中,建立 AIA 标准 LOD 400

或者国内标准 LOD 4.0(零件级)的 BIM 模型需要投入大量的资源与精力,因为这个级别的 BIM 模型包含了全面并且详细的施工细节[11]。如果在设计阶段未能充分将各设计专业的图纸进行协调,在依据 LOD 400 或者 LOD 4.0 建立 BIM 模型的过程中,会在修改与调整上消耗更多的精力,这将会产生许多不必要的资源浪费。这被认为是一种 BIM 的典范,所以不需要投入额外的精细化管理[35]。尽管采用 LOD 350 的标准需要投入一定量的资源,但是 LOD 350 能针对 LOD 300 对设计做出空间协调的优化,减少后期在修改上所消耗的精力(图 8)。

The clash between building components happens frequently during construction stage because of the insufficient detail level of design documents[3]. Therefore, an efficient solution is demanded to improve design quality during construction documents design phase. (Figure 9) illustrated the relation between different components and highlighted their potential clash. BIM models in LOD 350 require presenting actual size and shape, also it requires to develop connection joints[11]. Therefore, it would be advantageous to enhance spatial optimization at in during the modelling process by providing higher and accurate level of details.

由于设计交付图纸深度的不足,各构件在施工中容易频繁发生碰撞[3]。所以,在施工图设计阶段,需要一种有效的参考信息来提高设计在空间协调上的质量。图 9 列举了不同构件之间的关联,着重表示了一些容易发生碰撞的部位。LOD 350 要求模型各构件建立真实的尺寸和外形,并且要求建立目标构件与周边相邻构件的连接部件[11]。所以 BIM 模型在这个级别中可以为设计团队提供更多有效的参考细节,来对空间协调进行进一步的优化。

The major different between LOD 300 and LOD 350 is the fact that objects can be linked and interconnected[11]. In (Figure 10) is illustrated the detail requirement of each component in different LOD in more detail. Components from different disciplines have different requirements, LOD 350 requires MEP (Mechanical, Electrical and Plumbing) and HVAC (Heating, Ventilation and Air Conditioning). As a result that requires to build actual spatial coordination[11]. Spatial coordination can be efficiently optimized based on this level of BIM model. Therefore, compare to LOD 300, this research consider BIM models at LOD 350 level can show advantages in spatial coordination and thus improve the design requirements.

LOD 350 与 LOD 300 的关键不同之处为,LOD 350 要求建立目标构件与周围构件的连接件[11]。图 10 列举了各构件在不同 LOD 中的要求。不同专业的构件在细节上有着不同的要求,LOD 350 规定机电和暖通专业的 BIM 模型构件须建立与现实相一致的净高和空隙[11]。根据这个级别的 BIM 模型,空间协调能被设计团队进行有效分析并且优化。所以本研究认为 LOD 350 相比 LOD 300 可以在施工图设计的空间优化中发挥极大的优势来提高空间协调的质量,以此提高设计团队的业务能力。

According to the features of LOD 350, this level of BIM model will help design team to improve review and constructability through visualization (using tools

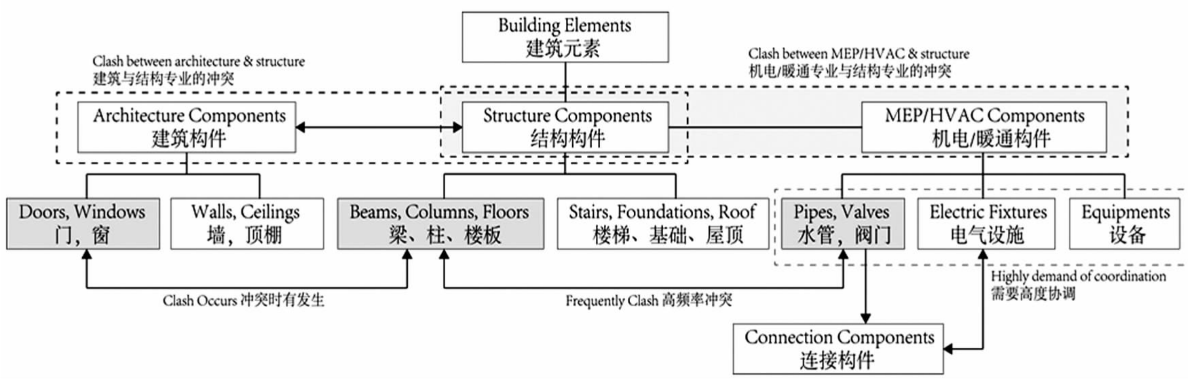

图 9　各构件潜在碰撞

Fig. 9　Potential clash between components

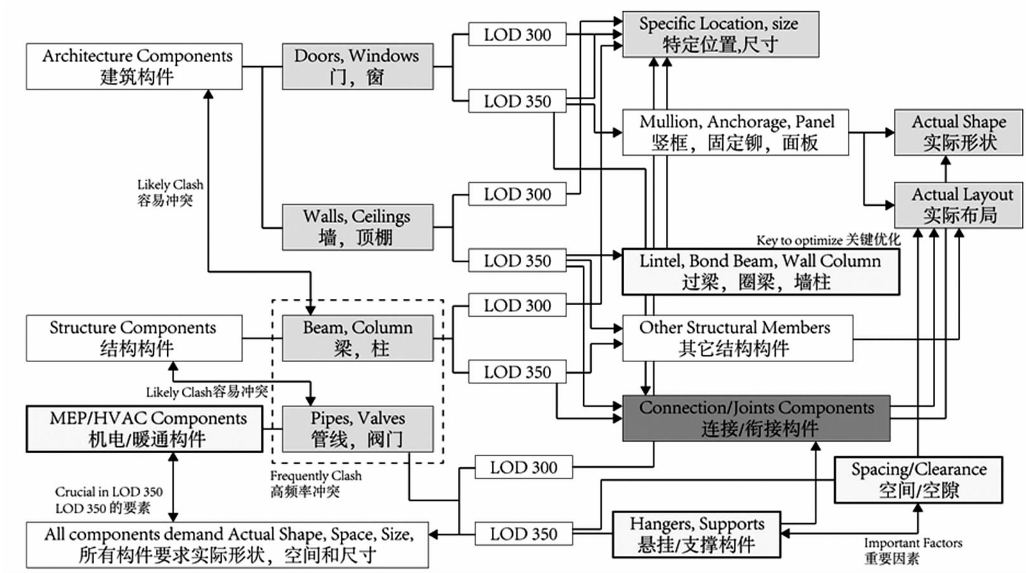

图 10　LOD 350 在不同建筑部件中的精度要求

Fig. 10　LOD 350 Specification in Different Building Components

such as HoloLens, HTC Vive etc) and simulation through gamification. The next section uses the scenario on the use of LOD 350 in Ningbo, China. Researchers tried to identify the impact of LOD 350 in construction documents design and assess the effectiveness of it to improve design quality.

根据 LOD 350 的特性,这个级别的 BIM 模型能通过可视化(采用 HoloLens 和 HTC Vive 之类的硬件工具)和游戏化的模拟来帮助设计团队提高对项目审阅的能力,同时能提高项目的可施工性。下一章节将通过一个位于浙江宁波,并且采用了 LOD 350 的场景案例,来分析来讨论 LOD 350 在施工图设计中的作用。本研究着重于确定 LOD 350 的作用,以此评估 LOD 350 对提高设计整体质量的有效性。

4　用例场景 Use Case Scenario

Considering the case study methodologically approach, researchers used a use case scenario to validate the process, in fact a kitchen of a small residential project. The project data provided under ethical approval by Zhejiang Jingwei Engineering Design Co., Ltd to be used by the University of Nottingham Ningbo China for the shake of this projects. In a more detail the kitchen includes multiple disciplines. Each discipline contains multiple system and components, for example, water supply, hot water, sewage, ventilation, lighting etc. This project implements BIM through the entire process, using LOD 350 (filling the gap between LOD 3.0 and LOD 4.0 in China) to model each component, integrated and checked each system in the master model, which achieved good design results.

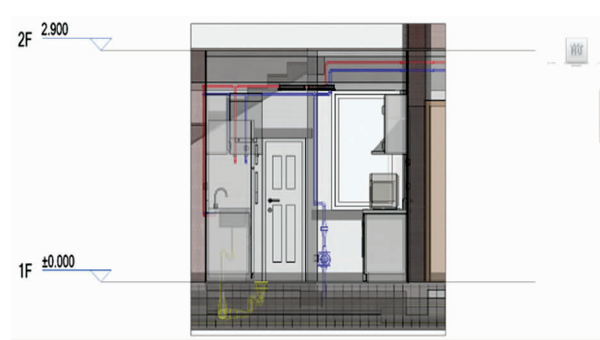

图 11　LOD 350 优化的模型

Fig. 11　Optimized Model at LOD 350

考虑到案例研究中的方法论,研究人员采取用例场景通过一栋小型住宅的厨房设计来对过程进行证实。项目数据由浙江经纬工程设计有限公司提供。厨房的设计包含了多个专业,在每个专业中包含许多系统和构件,例如:供水系统,热水系统,污水系统,排烟系统,以及照明系统等。本项目在设计的过程中全程应用了 BIM 技术,通过 LOD 350

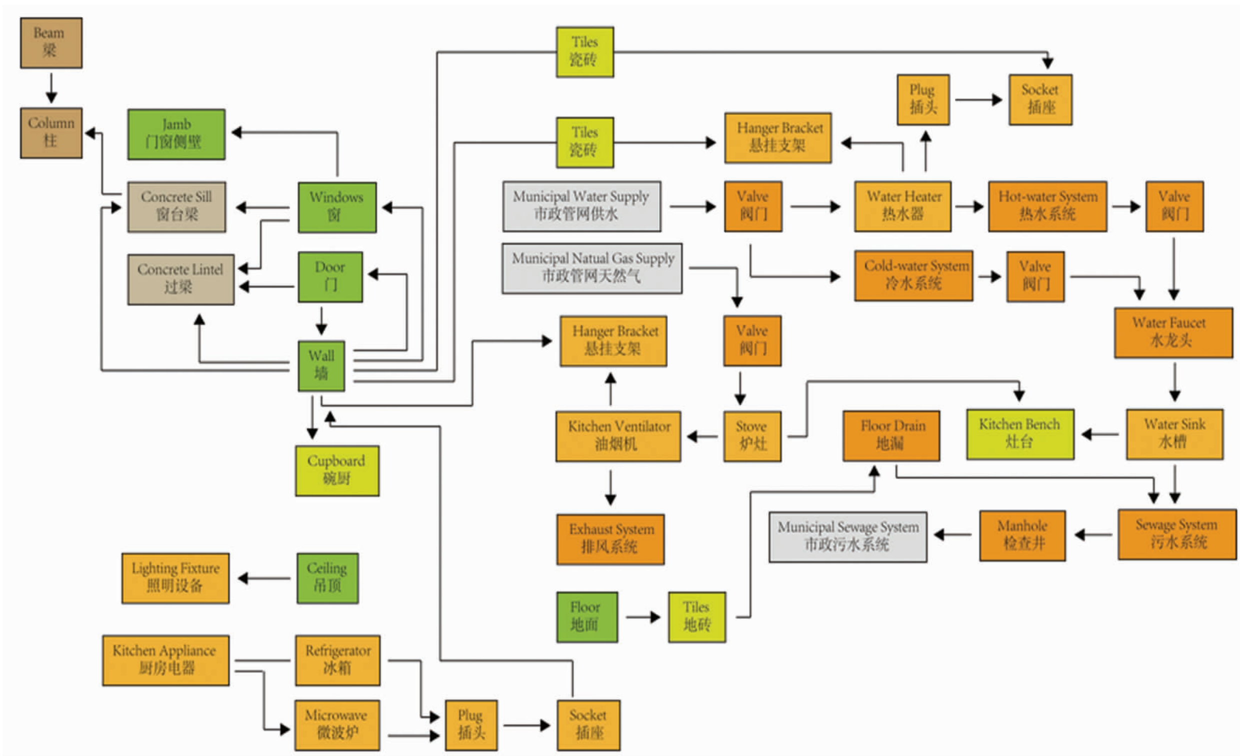

图 12　土建各构件之间的联系

Fig. 12　Interaction Between Building Components

标准(为填补国内 LOD 3.0 和 LOD 4.0 标准之间的空白)对项目各构件进行了建模,并对各系统在主 BIM 模型中进行整合与优化,最终取得了良好的设计效果。

The project lists all building components in kitchen during the BIM implementation, classified these components based on their discipline and analysed their relation (Figure 12). Before develop model into LOD 350, this project assesses and evaluated the demand; based on the relation of components in different system, this project evaluated the impact of these components to design coordination in LOD 350. Meanwhile, this project reviewed BIM models at LOD 200 and LOD 300 to explore those issues need to be addressed in LOD 350. The results are,

(1) Spatial relation between lintel and structural beam;

(2) Spatial coordination between plumbing components and mechanical equipment;

(3) Spatial coordination between appliance and room space.

Based on these analyses, this project developed BIM model based on LOD 300, enhance those important components to LOD 350 to coordinate space and optimize design.

本案例在 BIM 的执行过程中,首先对厨房内的所有构件进行了详细的统计,对这些构件根据所属专业进行分类,并且分析了各构件之间的关联(图 12)。本项目在建立 LOD 350 级别的 BIM 模型之前,对项目的需求和目标进行了调查和评估,通过对组成各系统的构件之间的联系来评估这些项目构件在 LOD 350 级别时如何作用厨房整体的设计协调与优化。同时,通过审阅 LOD 200 的方案设计模型与 LOD 300 的施工图设计模型来总结需要 LOD 350 所解决的问题。分析结果如下:

(1)门窗过梁与结构梁之间的空间关系;

(2)水管构件与相应机电设备之间的空间协调;

(3)厨房电器与整体使用空间之间的协调。

根据前期分析,项目对 LOD 300 级别的 BIM 模型进行深化,对重点部位建立 LOD 350 级别的 BIM 模型来对空间协调进行检测和优化。

Based on different disciplines, this project developed each important component to LOD 350 in Revit, and then linked these components into master model. During the integration, it detects those highlighted area exists clashes, through carefully review, these clashes are mainly including,

(1) Structural beam with Window;

(2) MEP system with Structural beam;

(3) MEP components in architectural space;

(4) Appliance in architectural space.

Through enhancing important area based on LOD 300, this project detects spatial clashes and made efficient modification. The requirement of LOD 350 to each component is to match with real objects, which are helpful to find potential problems through BIM models, especially during MEP enhancement design. This project adopt LOD 350 during BIM implementation, enables design team to make efficient spatial coordination and optimization, which improved the design quality. That aligns to digital assets of buildings, but this is beside the scope of this research.

根据不同专业,本项目采用 Revit 软件对重点部位进行了 LOD 350 级别的建模,通过链接的方式在主 BIM 模型中进行整合。在整合模型的过程中,通过检测,发现这些重点部位在许多构件在空间上存在相互冲突的情况,经过仔细分析,这些冲突主要包含:

(1)结构梁与窗户之间的冲突;

(2)给排水系统与结构梁之间的冲突;

(3)给排水构件在建筑使用空间上的冲突;

(4)电气设备在建筑使用空间上的冲突。

通过对 LOD 300 级别的 BIM 模型进行重点部位的深化,各构件在空间上的冲突通过可视化的模拟得到了及时的发现并进行调整。LOD 350 对各构件的精度要求是达到与现实相一致,这非常有利于通过 BIM 模型来发现空间上潜在的问题,尤其是在机电专业的深化设计上。此项目采取 LOD 350 级别的 BIM 模型,设计团体对建筑整体的空间协调做出了及时的优化,提高了施工图设计的质量。这同时匹配建筑数字资产所需的要求,但是数字资产不在本研究的范围之内。

LOD 350 requires building components have accordance with real object and have connection joints to simulate real space situation. The biggest contribution of LOD 350 to this project is the coordination with the MEP, architecture, and structure components. The spatial clash of MEP components is one of the largest problems during the design stage. Therefore, extra human workload is required to improve design and operational quality of the asset. Through this scenario, this research analysed and assessed the successful process, which comes with the conclusion: LOD 350 can realistically be implemented during BIM modelling process aiming to improve design, building's functions and arrange an improved spatial design specification.

LOD 350 级别要求 BIM 模型的构件在外型尺寸上与现实保持相一致,同时要求建立起各构件与周围构件的连接件来确保在空间上的真实模拟。本项目中 LOD 350 对项目设计最大的贡献在于对 MEP、建筑和结构在空间上的协调,而 MEP 在空间上与其它专业的冲突往往是影响设计质量的最大因素之一。所以,额外的人力需要被投入,以此来改善资产设计和运维的质量。通过这个场景案例,本研究分析和评估了项目成功的过程,得出的结论为:LOD 350 可以被实际地应用到 BIM 建模的过程中,为此来提高设计的质量、项目的功能和空间上的协调。

5 研究结果 Findings

The result of this research have shown: a) the problems that cause inefficient coordination during the design process of construction documents is lack of enough details for different disciplines and is lack of reference name for others to make correction, b) well-coordinated design documents can reduce errors during construction stage to ensure the delivery time and c) BIM model in LOD 350 can simulate each building components in such high level of detail, where design teams can improve spatial design optimization. (Figure 13) Illustrated the role and function of LOD 350 during construction documents design phase. Adoption of LOD 350 during BIM implementation can help design team and construction team to make better project and design review, which can reduce project uncertainties and help its successful delivery. In addition, this collaborative culture will be enhanced because team members to spend more time together to review the digital representation of a project and thus their knowledge level and understanding of the project will be improved significantly. Though, more important is that LOD 400 will be more accurate, therefore, the implementation of construction process will be more effective. In addition, when Asset Information Modelling (AIM) will be submitted to the client for use, it will contain more " accurate" building information that can be managed or modified based on the needs of the project investor.

本文的研究结果表明:a) 导致施工图设计阶段低效协调的主要原因是各专业缺少足够的信息参考细节,并且缺少能提供其它专业进行修改的参考名称;b) 在施工的过程中,充分协调的设计图纸能够帮助施工减少错误来确保项目的按时竣工;c) LOD 350 阶段的 BIM 模型能够针对项目的构件进行高精度的模拟,所以设计团队可以有效提高空间优化的能力。图 13 展示了 LOD 350 在施工图设计阶段的角色和作用,在建设项目的 BIM 应用中采纳 LOD 350 能使设计方和施工方对建设项目做出更好的评估来有效降低项目施工中的不确定性,以确保项目的按时竣工。另外,通过这种方式,团队的协同合作环境将会被有效提高,因为团队成员会投入更多时间来一起对项目的 BIM 模型进行审阅,所以设计团队将会显著提升对项目的认知与了解。最重要的是,通过 LOD 350 的应用,LOD 400 级别的 BIM 模型将能够更加精确地建立来更好地帮助施工过程的高效实施。此外,当建立资产信息模型(AIM)并且进行交付的同时,模型能够针对甲方的需求来提供更多精确的项目信息,为建筑后期的运营提供有效支持。

6 结论和下一阶段研究 Conclusion and Future Studies

Since China has introduced LOD 3.0 and LOD 4.0 in BIM Modelling process, still there is a gap on project delivery because quality level of information (LOD) is low and its quantity (Terabyte) can lead to such as: mismatch information, not accurate data, incorrect files names etc. As a result, project coordination is affected, and the project has more chances to fail.

国内的 BIM 交付标准为建模过程制定了 LOD 3.0 和 LOD 4.0,但是在这两个标准之间存在着空缺。因为在设计过程中信息深度(LOD)的不足以及信息量(太字节)的不足会导致一些问题,比如:信息搭配错误,不精确的数据,不正确的文件名称等。所以,项目设计的协同合作会受到影响,并且会导致项目产生更大几率的失败。

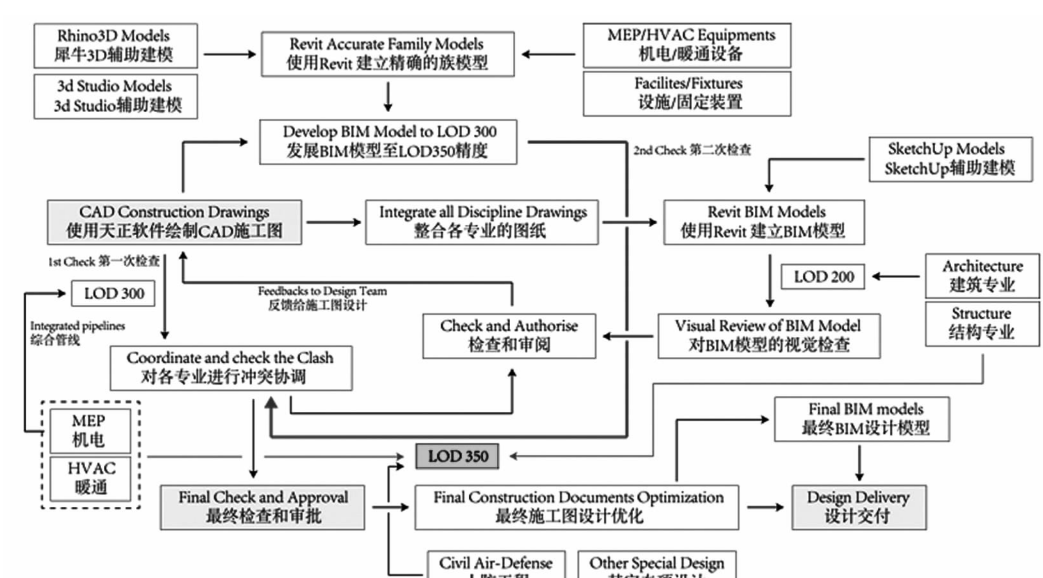

图 13 LOD 350 的作用与角色

Fig. 13 Role and Function of LOD 350

Considering the impact of applying LOD 350 in a project in Ningbo China, results shown its success to eliminate the above errors. Consequently, this idea (LOD 3.5) could be introduced and practiced in both national and provincial level.

考虑到在实际项目的实践中采用 LOD 350 标准的作用,研究结果表明这个标准能够成功消除上述在设计协同合作上的问题。所以,LOD 3.5 适合被加入 LOD 3.0 与 LOD 4.0 之间,并且在国家级与省级的标准中进行推广和实践。

However more studies must be conducted to provide a more comprehensive understanding of its implementation within AEC enterprises and construction projects. Moreover, beyond the contribution of this research in policy level, the team can foresee also huge impact in projects′ performance due to the need to design, construct and operate buildings in a more integrated and collaborative manner.

但是,这需要进行更多的研究来全面了解这个标准将如何在建筑、工程、施工企业和建设项目中实施。更多的是,这个研究除了在标准制定层面进行论证之外,研究团队预测到,在项目执行的过程中,对整合设计和协同合作需求的提升将会极大改善项目的绩效。

As a result, the future of BIM in China would be the introduction of LOD 3.5 where stakeholders can coordinate project information (graphical, non-graphical and documentation) in a more holistic perspective, based also on ISO 19650 that is the latest internationally recognised standard/policy in building information modelling and management.

因此,未来的国内 BIM 标准如果推出 LOD 3.5,基于国际标准化组织在 BIM 建模和管理上最新推出的 ISO 19650,项目各参与方可以对项目的信息(图像信息、非图像信息、文件)从整体的视角进行协调。

In this occasion China is entering more in the international market dynamically because those enterprises are part of BIM driven projects can meet clients′ requirements based on time, cost, and quality.

借助这个机会,中国建筑企业能够更加充满活力地进入国际市场,因为这些企业将能够更好地对项目进行基于 BIM 的管理,来满足业主方对时间、成本和质量上的要求。

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Impact of Level of Development（LOD）350 of BIM Models in Building Construction Documents Design

Yang Tianlun[1], Georgios Kapogiannis[1], Byung-Gyoo Kang[1], Robin Wilson[2]

（1. *University of Nottingham Ningbo China*, *Ningbo* 315040, *China*;
2. *University of Nottingham UK*, *Nottingham NG*7 2*RD*, *UK*）

Abstract: In order to help building design practise to have better coordination between different disciplines and improve design performance during construction drawing phase, this paper investigated the problems in design management and studied the characteristics of Level of Detail (LOD) 350 to analysed the impact of LOD 350 in BIM implementations, through case scenario to discuss impacts of LOD 350 in construction documents design phase and to assess the effectiveness of LOD 350 to improve quality of construction documents delivery.

Key Words: Construction Documents Design; BIM; LOD 350

作者简介 Authors Introduction

Tianlun Yang is a PhD researcher in BIM at Department of Architecture and Built Environment, University of Nottingham Ningbo China. He graduated from Clemson University (USA) with B. A. in Architecture and University of Sheffield (UK) with M. A. in Architectural Design. He has many years working experience in Zhejiang Jingwei Engineering Design Co. Ltd., has involved in many architecture and BIM project. He is also graduate teaching assistant and research assistant in University of Nottingham Ningbo China.

杨天伦,宁波诺丁汉大学建筑与建筑环境系 BIM 方向在读博士研究生。本科毕业于美国 Clemson University 建筑学专业,硕士毕业于英国 University of Sheffield 建筑设计专业。他在浙江经纬工程设计有限公司拥有多年的工作经验,参与过众多建筑设计和 BIM 的项目,同时在宁波诺丁汉大学担任教学助理和研究助理的职务。

Dr. Georgios Kapogiannis is currently an assistant professor and PhD supervisor of BIM at the University of Nottingham Ningbo China, and an associate member of the center for architectural engineering and informatics at the University of Nottingham, UK. In addition, Dr. Kapogiannis is the BIM director of the Geospatial and Geo-hazard research group at the University of Nottingham Ningbo China. He holds a PhD degree in architecture and project management from the University of Salford School of Architectural Environment (THINKlab) in the UK and has won an EU scholarship. Dr. Kapogiannis has been a member of the peer review college of the Economic and Social Research Council (ESRC) since 2015 (invited); and the chairman of Charted Institute of Building (CIOB) in Coventry and Warwickshire from 2013 to 2015, West Midlands chapter Committee; co-founder and member of the UK BIM alliance, BIM East, from 2016 to 2018. At present, Dr. Kapogiannis is a core member of the digital building working group of the Chartered Institute of Building and a member of the China Association of Technology Entrepreneur (CATE) of the Ministry of Science and Technology of China (MoST). In the context of the international community of industry 4.0, Dr. Kapogiannis is good at contributing to the enhancement of digital transformation and collaborative cooperation in the Architecture, Engineering and Construction (AEC) industries through the integration of personnel and technical processes. Dr. Kapogiannis specializes in: Modelling and management of urban and building information models; Artificial Intelligence (AI); Gamification (series of games); Unified Modelling Language (including business process modeling language (uml-bpml)); mobile technology (wireless, 5g, optics, satellite); Internet of Things (IOT), simulation and Virtual, Augmented Reality; Big Data and Blockchain.

乔治·卡普吉安尼斯博士现担任宁波诺丁汉大学建筑信息模型(BIM)助理教授和博士研究生导师,也是英国诺丁汉大学建筑工程与信息学中心的准会员。此外,卡普吉安尼斯博士是宁波诺丁汉大学地理空间和地理灾害研究小组的 BIM 负责人。他拥有英国 University of Salford 建筑环境学院(THINKlab)建筑和项目管理的博士学位并且获得欧盟奖学金。卡普吉安尼斯博士自 2015 年起担任英国经济与社会研究理事会(ESRC)同行评议学院的成员(应邀参加);在 2013 年至 2015 年间担任考文垂和沃里克郡的英国皇家特许建造学会(CIOB) 主席,西米德兰兹分会委员会成员;在 2016 年至 2018 年间担任英国 BIM 联盟——BIM 东区的联合创始人和成员。目前,卡普吉安尼斯博士是英国皇家特许建造学会数字建筑工作组的核心成员,也是中国科技部技术创业协会的委员。在工业 4.0 的国际社会背景下,卡普吉安尼斯擅长通过整合人员与技术流程,为建筑、工程与施工行业(AEC)增强数字化转型与协同合作做出贡献。卡普吉安尼斯博士的专长是:城市、建筑信息模型的建模与管理;人工智能;游戏化(系列游戏);统一建模语言(包括业务流程建模语言(UML-BPML));移动技术(无线、5G、光学、卫星);物联网 (IoT)、仿真与虚拟、增强现实;大数据与区块链。

Dr. Byung-Gyoo Kang is currently the Assistant Professor in University of Nottingham Ningbo China and PhD supervisor in BIM. His research interest is BIM in construction management, value engineering, risk management, lean construction, sustainable construction.

姜炳圭博士现为宁波诺丁汉大学 BIM 方向的助理教授和博士生导师,他的研究方向为 BIM 与建造管理,工程经济学,风险管理,敬意建造,可持续建造。

Dr Robin Wilson was the Head of the Department of Architecture in the University of Nottingham UK Campus. His research area is Acoustics of complex structures such as whole buildings and aerospace structures using statistical energy analysis as a predictive tool. In addition, he works on Structural power flow measurement techniques and acoustics of porous materials. In addition, he is working on acoustic rendering of buildings using ray tracing software.

罗宾·威尔逊博士是英国诺丁汉大学建筑与建筑环境系主任。他的研究领域是使用统计能量分析作为预测工具的复杂结构的声学,如整体建筑和航空航天结构。此外,他还研究了多孔材料的结构功率流测量技术和声学。此外,他还在使用光线追踪软件对建筑物进行声学渲染。