大势所趋
——医疗设施设计引入“开放建筑”理念
A NEW IMPERATIVE: OPEN BUILDING IN HEALTHCARE FACILITY DESIGN

史蒂芬 · 肯德尔 丨 Stephen Kendall

翻译：张　宇 丨 Translated by Zhang Yu
校审：于松乔 丨 Proofed by Yu Songqiao

摘要　由于器材升级、医疗实践改革、人员变更和医疗技术更新等问题，医疗设施的建设从来不曾真正结束。而更重要的是，在项目开始阶段的规划、设计和建造与多年之后已改变的项目情况难以契合。为了使建筑做到可持续，业主需要知道如何制订能应对变化中的需求的任务书以确保建筑具有可变的能力，就像电气等基础设施系统中将部件根据使用年限分类，以确保不会因为使用寿命预期较短的部件更替导致更高级别的系统强制关闭或者损害这样的办法。这就需要我们从传统的决策制订方式转型到能同时适应建筑〝文化〞和设计手法变化的新型决策制订方式上去。
关键词　医疗设施　可变性　基础设施　开放建筑

Abstract　Healthcare facilities are never finished, due largely to changing requirements, medical practices, demographics and medical technology. Further, those responsible for their initial planning, design and construction are not the same as those who, years later, will manage their change. To be sustainable, clients need to learn how to demand healthcare facilities with the capacity to adapt to such changing requirements, just as infrastructure systems such as electric utilities are organized: parts with a long utility value are clearly separated from parts that change more quickly, enabling those more quickly changing parts to be replaced or changed without shutting down or downgrading the higher-level parts of the system. This requires a change in conventional decision-making, which constitutes both a change in "culture" and a change in design methods.
Keywords　Healthcare Facilities, Change, Infrastructure, Open Building

引言

众所周知，涵盖医疗设施在内的各种建筑，在或大或小的方面都体现着可变性，以确保其多年之后仍旧能够满足使用需求，即实现建筑的可持续性。

然而，客户们是否不再关注短期利益，而是用长远价值来判定医疗资产吗？回答是否定的。建筑师与工程师设计的医疗设施是否能够很好地应对不断变化的现实状况？答案依然是否定的。[1~6]

问题源于三个方面：首先，医疗设施的业主（不限于私人业主）仍没有魄力明确支持和投资长期项目，尤其是在未来情况并不明朗时。其次，个体知识水平的差异普遍存在于建筑师与工程师中，他们并非都掌握了设计可变建筑的创新能力。最后，监管环境仍然没能完成全面的转型以完全适应千变万化的现实情况。

以工程师和建筑师为例，技术人员倾向于用专业知识去解释他们面对的问题。[7]然而问题的根源并非是技术上的，相反，是由于业主和服务供应商还没有转变思维，依然沿用20世纪功能主义思想去思考医疗设施及其建设。我们仍坚信，启动项目需要对所有条件进行完整地功能性规划，其中包括建筑的用地面积、房间大小、周边状况，以及设备技术参数，然而这必然引发矛盾且导致无法实现较长远的价值。[8]

解决之道在于以开放建筑的理念去解读建筑设施，即采用基础设施系统。公路、公路上行驶的车辆以及其他公用系统——从供电系统到手术室便捷的进出口——都要用心考量。这些功能各异的系统可以通过三个重要特征来理解。

第一，跨越时空的分散式设计和规划职责；第二，等级划分，在维持较高等级不变的情况下，较低等级可以自由更改；第三，各等级之间有全行业的对接标准。

近几十年间，购物中心及办公楼已经展现出上述三个属性，虽然效果并不尽如人意。而今，医疗设施及住宅地产无法阻挡地要采用基础设施系统，成为社会和企业的发展趋势。

本文讨论了此种情况出现的原因，并为医疗设施建设提供基础设施系统，用来解决现今建设实践中的矛盾。

实现开放建筑的基本原则

希望建设的建筑能保有长久的使用价值，只能通过决策过程实现，并在此过程中要时刻认识到环境建设是永无止境的。决策制订必须通过设定带有长期使用价值的规划进程来应对不断变换的现实。当与居住设施相关时，使用价值本身并不是一个专业术语，使用和价值的概念存在于社会体系中，该体系认为物质环境的价值并不是一成不变的，而是与时俱进地同社会价值和愿景一起演变。

我们的研究表明改变的能力，或者说开放建筑，是一个设施全生命周期的基础。[9]即使它目前并没有成为一个行业标准，然而应该像LEED①及建筑规范一样，作为业主对设计及规划顾问提出的要求，而且应该突破权限范围及决策制订的限制，体现在所有的设计指南及送审文件中。

基于持续关怀的决策

众所周知，在设施调试完成前，由于最后一点改动，医疗设施仍处于不断调整阶段。举例来说，医疗机构在运营前若干个月聘任了新的外科医生，他可能要求以集中式手术套间配置来替换之前的线性布置方式。同时广为人知的是，由于组织重点的调整、人口结构转变、新医疗实践和技术的出现，以及保险政策的变化，医疗机构会在此后数年内不断进行各种方式的调整。

研究表明，“全生命周期”评价的概念备受推崇，然而却缺乏清晰的界定及严格的执行。我们的研究表明“持续关怀”的概念或许更合适，且其不应仅适用于借助此类设施恢复健康和提高身体状况的人群，同时也应适用于此类设施本身。这就说明，当前所关注的近期规划、预算、投资、设计、施工、调试及设施装配的观念一定会被持续变革的高瞻远瞩取代，尽管也称其为“全生命周期”的管理。这种长远眼光离不开前景规划、成本建模，以及通过数据收集用以估算长期的调节战略的投资收益。[10]

因此，在现实中面对医疗设施业主时，“设施维护”并不是一个恰当的概念或术语。如果业主期望他们的设施具有可持续性，同时可提供源源不断的运营效能和物理性能，那么就要在预算、核算、管理方面采纳更多的“可扩充”和“可持续改进”的态度和方法。

我们研究推崇的开放建筑设计模型，在全球商业地产中是司空见惯的。这看似非比寻常，因为商业地产的决策者通常被认为仅有短期兴趣，致力于快速收益、迅速回本和规避风险。或许正出于此种倾向，投资者在决策上异常敏锐。他们会做分离式决策，即将设施的长远基础构件（俗称“基础建筑”）与多变部分（俗称“装备”）分开决策。该决策模式在大型基础设施规划及运营中也非常普遍，例如在公路（公路与车辆是分离的）[11]和公共设施系统中，电力传输线路设计要适应（变化的）独立代理控制的下游用户的使用需求。

基于系统使用寿命的分离设计

上文指出，传统的建设方式是指一个设施在最初建设阶段，假定所有相关信息被一次性地汇总（俗称“整合”）。大家认为用这种方式才能使得预算固定不变。

相反，开放建筑决策过程需要应用一系列连续的决策模型。这些模型遵循的原则是，将拥有长期功能的部分与短期功能的部分分离设计。美国与欧洲的部分用户采用了这种模型，比如我们研究发现美国国防部卫生机构使用一套独立的建设协议，称为“初期装配和转型”（IO&T）来管理详细规划与设备建设，信息技术与医疗装备。与之类似，在快速进程项目中采用“增量资金减免”以允许注资，例如，早期的“基础计划”甚至可以在建筑物的详细设计完成前推出。

“开放建筑”系列决策模型包括三个“系统等级”。

一是主要系统，即基础建造。“开放建筑”包括结构、外墙和主要的（不变的）机械、电气及管道系统，预计将有100年的使用寿命（图1）。

二是次要系统，即硬装。所有组件和空间直接服务于功能，包括针对特定功能的一部分机械、电气及管道系统，预计将有10年～30年的使用寿命。

三是三级系统，即家具、固定装置和设备，如设备、家具、计算机系统和一些消耗品等短期投资项目，预计会在1年～5年内快速更换。[12]

设施决策的分离设计，应基于系统等级关注的全生命周期的使用价值来进行。就是说，三级系统能够实现改变却不会（过度）妨碍次要系统。次要系统（代表客户不断变化的任务、功能和空间需求）必须能改动且不破坏主要系统。

因此预期拥有长久使用寿命的建筑构件及空间应该严格及明确地与较短使用寿命的建筑构件及空间分离，而且这种分离必须应用于所有的阶段，包括规划、预算、设计及建设（改造）过程。

分离的原因是为确保短寿的建筑构件（例如服务于特定功能的构件）不会破坏或改变（或者仅做最小变动以快速完成）计划长久使用的构件（例如支持大量建筑功能的构件与结构）。例如，改变短期使用的墙壁不需要拆除主体结构，更换电源插座不需要破坏其所在的墙壁。

在上述三个“系统等级”（主要，次要，三级）中，可能会发现“固定”及“可变”的部分。例如，外墙被划入主要系统。但是在“外墙”范畴中，某些部分可能要比其他部分更需要频繁地更换或升级（比如窗户需要在整个建筑外墙面层之前更换；如此一来，建筑外墙应是“固定”类，而窗户属于“可变”类）（图2，图3）。

确保主要系统无误是重中之重

确保主要系统无误与修正城市交通及公共空间结构的举措，具有异曲同工之效，因为它是为城市结构的百年以上的演变搭建平台。在此情形下，街道及城市公园一起构成了“固定”结构，公共设施建于其间，这些空间的多样化及用途则是“可变的”。

基于相同的原因，面对医疗功能和运营演变，主要系统的寿命（及能源效率）成为重中之重。主要系统应该为社会、业主及城市肌理的特色提供长效的利用价值。这意味着主系统规划不能仅依据现有的知识、偏好与数据。

这是最初也是最为重要的分离设计，而且在组织文化中特别难以实现，这种文化曾经按照统一的、自上而下的管控模型来运转，在这个模型中所有部分都彼此依赖。因此，大部分被推荐的灵活性要求应确保主要系统准确无误，然后使其与次要系统分离。

次要系统与三级系统的易变性

全球研究表明医疗设施的次要系统（反映出变化的功能需求、医疗行为等）和三级系统（包括正在迅速发展和微型化的移动设备）中，最先进的系统已经很好地展现了所需的灵活性（分离）。例如，由大型供应商（如Herman Miller 和Steelcase）提供的全面医疗系统，表明次要系统和三级系统之间很难分得清楚：墙体、设备及水暖电系统组件绑定在一起，由于存在专利保护的问题，所以要在同一个供应商提供的“产品”中寻求解决之道。当不同的公司送货并安装这些整体解决方案中的要素时，对接工作并不顺畅。

在“开放市场”中，次要系统和三级系统间的对接必须在现场解决，这一情况已经被IO&T协议详细研究并证实（初始装配和转型——大部分等同于三级系统）。这些协议中，两个等级间相互依赖一再体现，并且多次成为质量掌控、重新建设、问责诉讼问题的根源。

次要系统和三级系统拓展的智能化发展还有很多工作要做。这也需要进一步考虑由“开放”市场（目前是国际化的市场）提供的产品与组件的系统等级“之上”和系统等级“之间”的接口。接口在等级“之上”的对接例子是在次要系统中的电缆布线与墙体对接的问题非常棘手，亟须解决。新的解决方案已经可行，但这会破坏股东们的惯例，而且他们并不想改变惯例或调整供应链关系。

接口在等级“之间”的对接例子体现在主要系统的电缆和次要系统的电缆对接，次要系统（墙体）和三级系统（设备）之间的电缆对接。

对于此类基于性能灵活性对接（大量存在）需求的发展状况研究需要单独展开另作讨论。

综合决策到序列决策

将图3中表现的分离原则转译成递推模型，我们所推荐的序列（图4最

图1　瑞士伯尔尼INO医院的主要系统

主要系统　　次要系统　　三级系统

图2　三个“系统等级”示意图

后一行）实际上是IO&T（初步装配和转型）协议中近期实施分离的一种演变，此协议已被美国国防卫生机构采纳（图4的中间一行）。

对序列决策过程（对于新建设和现有设施的全面激活）的根本理解应为，从建造/更新的决定，到集资、规划、施工、调试、迁入及适应新要求的后期改造，整个过程需要数十年，然而所有事实和需求无法在过程伊始全部掌握。

从最初建设延续到整个建筑生命周期的决策需要由不同的设计团队和领导团队逐步制订，别无他法。

开放建筑的基本要求

通过全面总结世界各地医疗设施最佳案例，得出如下开放建筑的要求。[10]

场地扩容能力（包括场地基础设施、停车场等）；建筑扩容能力（竖向的和/或水平的）；结构体系的几何形状（简单的、规则的几何形状较为理想）；自然光线（针对所有居住空间，自然光线是诸多准则中的必备条件）；层高要求（为水平装置提供足够空间）；楼板承载能力（容纳合理范围内的设备负载）；最少量的内部结构墙（如需内部承重墙，应在容量分析后进行定位）；可变外立面（在不破坏主要系统结构前提下，可移除外立面）；基于预期使用价值的系统分离（加强建筑适应性，当部分内容改变时，减少技术层面和社会层面的冲突）；次要系统布局及水暖电系统的灵活性 （在主要系统内必须为次要系统对应的用途，平面布局，机械、电力和管道系统留出足够空间）；预留未来垂直机械设备管道（通过研究发现所有的新功能都需要额外的垂直设备管道）；多功能的房间布局（可以容纳多样功能及设备的房间应尽可能多）；病房规模可调整的能力（单间还是半私人病房仍存争议，因此主要系统的设计应同时满足两者需求）。

通过设计汇报实施开放建筑理念

在每次委托设计汇报中，业主通常要求建筑师和工程师准备图纸和详细说明书，包括概念汇报、草图设计阶段汇报、方案扩初阶段汇报等。开放建筑的落实需要建筑师和工程师明确地表明他们是如何遵章设计的，同时业主必须监督执行。这意味着设计汇报的要求必须清楚地规定每次汇报的设计深度，包括空间和装置的调整。就是说，主要系统的图纸（建筑及机械系统）必须清楚地展现在哪些范围内，次要系统可以进行改变等。

设计汇报要求建筑师和工程师必须定期接受评估和指导。随着经验累积及对承诺履行监察程度的提高，业主必须提高手段、技能及文化来更新这些要求。

高性能和可持续发展的要求

领先的医疗设施的业主正尝试应用高性能和可持续的基础设施和设备，这是目前美国联邦政府机构强制执行的，并将逐步在全行业普及。

下一个步骤是明确地将开放建筑指令与可持续性指令相关联，此势头已然明确无疑。例如，建筑设计与施工的LEED v4（领先能源与环境设计）中关于医疗设施的灵活性设计一节用了如下表述：“通过加强灵活性和适应性及延长组件寿命，来节约建筑施工与管理的资源①。

让开放建筑具有弹性及气候适应能力

通过与权威专家的研讨和近期文献回顾得出如下结论：弹性（极端自然现象和人为事件的承受及恢复能力）和适应气候变化的能力是开放建筑的主要设计原则。虽然设施改变的原因不同（功能升级及满意程度提升推动对开放建筑的需要），但其需要相同的性能，即减少因一部分的改变导致整体改变的涟漪效应。

在弹性及气候适应的决策中，需要进行经济和政治方面（社会/组织/行为）的评估来估算实施弹性策略的效能和投资回报。同样的评估也适用于对医疗设施的适应变化能力的评价。即如果实现了开放建筑，其弹性及应对气候变化的能力也能轻而易举实现。这就是说，上文提到的开放建筑策略与其他策略相比更利于实现弹性及气候适应性。

例如，英国剑桥大学和拉夫堡大学致力于为升级现有医疗设施以适应气候变化（如不断上升的气温）制订发展策略，专注于能源系统升级，且不会增加能源预算。采纳我们推荐的一些策略建造的开放设施将会在支持此类升级改造中走得更远②。

可变性和可持续建筑的联系——在技术之上

迄今为止，关于高性能和可持续性建筑的讨论——在发表的技术报告中，在学术和行业会议上，在客户组织内及在服务供应商之间——普遍缺乏对决策制订模式的根本反思。这些讨论一直专注于技术。关于技术的讨论更受青睐是因其预设的科学客观性和技术理性。

另外，有关决策控制的讨论必然涉及控制权力分配的问题（在一个复杂的基础设施系统中仅凭一人无法掌控全局），因此这里不存在技术理性可以证明的正确答案。有的文献（来自MIT的Eric von Hippel教授）也称之为“任务划分”。[13]组织机构受技术理性浸润已久，但又无可避免地在分散控制的复杂模式中艰难运营，同时由于没有完善的理论来建立连接技术与管控的政策和实践，因此在决策中规避了系统化的重建。在大型政府机构中此种艰难状况尤为明显，这些机构日益壮大，累积了各种决策模式，几乎没有全面修正的机会。

我们研究考察的这些案例的共同点在于：存在利益分级。最高级的利益是基本资产的长期存在与维护。在美国联邦机构的体系中，最高级的利益关注者是美国国会，理论上，他们关注的是长远的公共利益。在利益等级的最末端是医生及其他照顾者，他们是直接的服务提供者，在道德和专业领域致力于用最好的药物、技术及人才提供最好的关怀。以下模式可以解释系统等级与“利益”的对应关系。

主要系统→中央组织 （机构、理事会）

次要系统→当地医疗设施管理组织

三级系统→医护人员

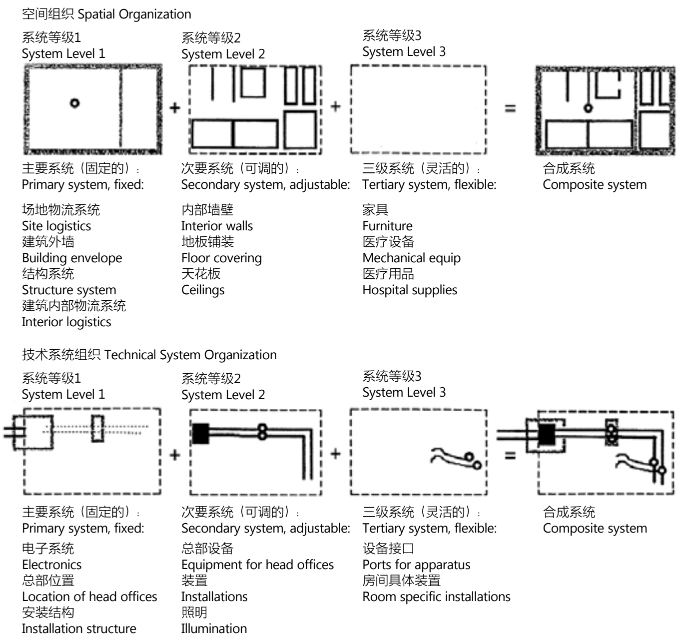
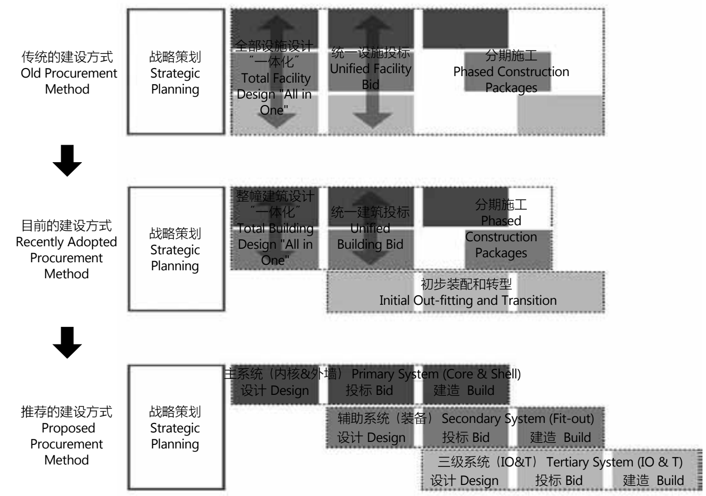


图3 三个“系统等级”分析图
（图片来源：Office of Properties and Buildings, Canton Bern, Switzerland）



注：“传统”的建设方式或许适合简单项目，因为其涉及的所有信息可以一次性获取。但是随着项目规模和复杂度的提高，以及从规划到建成的耗时增加，分离设计和序列决策愈发重要。
Evolution from a parallel to a serial decision-making process. The "old" procurement model may be suitable for simple projects in which all information can be known at once. But as project size and complexity increases, and as the time from planning to realization increases, the more important decoupling and sequencing of decisions becomes.

图4 从平行到序列决策过程的演变（作者绘制）

转换视角

引言中指出，大部分业主与设计服务供应商仍然保持着20世纪植根于功能主义形成的建筑环境的理念。这个理念源自科学理性主义，意味着在建筑环境建设方面，基于充足的研究，可以得到正确且恒久的针对人的行为及所需的物理环境属性的结论。但是我们的研究表明，此观点与现实并不一致，现实中建筑环境在不停变换。更为重要的是，新知识为大众的偏好与愿望提供了新答案，过往的假设终将过时。

因此，我们的研究认为必须要转变视角：

静态设施→动态的资产

关注设施初期建设的决策→随时间改变的决策（资产将随时间而转变）

关注技术的灵活性→关注设施全生命周期中序列决策的灵活性

与可持续性相分离的灵活性→灵活性激活可持续性

可选择的灵活性→必备的灵活性

结论和对未来行动的建议

众所周知，健康的建筑环境可以通过自身调节适应多样的、不断变化的人居使用需求。同时，我们曾经面对的宏大和快节奏的项目——从城市设计尺度的项目到建筑改造的精细工作——需要将设计责任巧妙地分配。可持续发展告诉我们节约的重要性，迫使我们根据建筑构件的使用寿命差异来将其进行分类。

我们的研究主要集中在目前决策过程中的不足和需要转换的建筑环境中的基础设施模型。我们还发现各类型地产的普遍发展趋势——包括但不限于医疗设施——可以理解成一种基础设施的新形式。此趋势是世界各地社会推动的结果，并非新生事物，但却缓慢而清晰地改变着我们对待建筑的方式。可以断定这些动力——更大型的项目，更多的明显的改变，日益提升的精良设备和公共服务——不会消失。因此，我们认为，建筑作为基础设施观念的提出帮助开放建筑得到认同和发展，这对地产发展、建筑，包括医疗设施都具有深远的影响。

实现这一目标过程中面临的问题都是非常重要的。必要的专业方向调整（包括建筑教育和工程教育）、管理和核算方式的改变都会导致速度、方向和质量的变化。但是要注意的是我们在研究中指出的视角变化是源自于缜密的经济论证和应对市场调控的意愿。此时建立更明确的研究和发展平台的需求已经悄然到来，但这并不是新的设计理念，而是需要认真对待的现实。

大势所趋

所有建筑都必须进行防火设计如何变得理所当然？所有的居所中都要求自然采光与通风，以及所有建筑必须节约能源又是如何变得理所当然？

这些要求成为理所当然是由于全社会理解这些标准是公共利益的一部分，它对大众和个人都有益。

曾经这些标准也遭遇抵触，接纳就意味着人们要改变习惯、方法和态度。事实上，应用这些标准会花费更多，但是假以时日，公众会认同这些标准是有益的且必需的。建筑环境的历史表明在建筑中提升设计标准是永恒的趋势。

现在，可持续发展是（几乎是）理所当然的。几乎所有人都认同，使一个建筑具有持续性——甚至零能耗——在长期运营中将节省金钱和资源，因此需要广泛认可。事实上，可持续发展在历史城市中从来不是问题：一步步地改变，资源利用与社会准则间形成的动态平衡一直持续千年。当今，在多方努力下，建筑的可持续性正如防火规范一样，已成为大势所趋，无可辩驳。

现在是时候在医疗设施设计和规划中让开放建筑观念成为常态，这是一个必然趋势，它会像防火规范与可持续理念一样无处不在。■

Introduction

Everyone knows that the buildings we construct – including health care facilities – will adjust in big and small ways, to assure their usefulness over many years – that is, to be sustainable.

But, are clients shifting their expectations from short-term goals, and learning how to demand healthcare assets with long-term value? The answer is negative. Are architects and engineers doing a good job designing healthcare facilities for the realities of constant change? The answer is also generally no. [1-6]

The problem lies in three domains. First, healthcare clients – especially but not only private-sector clients – do not yet have the incentives to articulate and fund long-term missions when the future is uncertain. Second, there is an uneven distribution of knowledge among architects and engineers about how to design-in capacity to accommodate change. Third, the regulatory environment has not yet made the transition to mandates congruent with the realities of constant change.

Technicians such as engineers and architects tend to define the problems they are asked to solve in technical terms.[7] However, the root of the problem here is not fundamentally technical. The problem is, instead, that we – clients and service providers – have not yet moved beyond the 20th century functionalist way of thinking about facilities and facility acquisition. We still believe in the need for complete and integrated functional programming of the entire asset – including building footprint, room sizes, adjacencies and equipment specifications – to get the process started. This inevitably leads to conflict and suboptimal long-term asset performance.[8]

The solution lies in an Open Building way of understanding built facilities – that is, as infrastructure systems. Highways and the vehicles that run on them, and utility systems – from power generation to convenience outlets in operating rooms – come to mind. These heterogeneous systems can be understood by three important characteristics: 1) Distributed design and planning responsibility across time and space; 2) A hierarchy of levels, in which lower levels are free to change without disturbing the higher levels; 3) Industry-wide interface standards between levels.

Shopping centers and office buildings have exhibited these attributes for decades, albeit imperfectly. Now, healthcare facilities – and residential real estate assets – are inexorably coming to adopt the infrastructure model as a social and enterprise-level imperative.

This paper discusses why this is happening, and offers an infrastructure model for healthcare facilities procurement that can overcome the conflicts inherent in current procurement practices.

A Fundamental Principle For Achieving Open Building

Acquisition of assets expected to have a long use-value can only come out of decision-making processes that recognize that the built environment is never finished. Decision-making must recognize the reality of continuous transformation by setting in place planning processes congruent with long-term use-value. Use-value itself is not a technical term when associated with inhabited facilities: the concepts of use and value exist in a social body that understands that the value of the physical environment is not a static phenomenon, but is evolving in accordance with evolving societal values and aspirations.

Our research has shown that capacity for change, or open building, is fundamental to a facilities life-cycle (whole-building life) agenda.[9] Even though this is not yet an industry standard, it can and should be a requirement given by clients to their design and planning consultants – like LEED[①] and building codes – and should appear in all design guidance and design submittal documents, cutting across lines of authority and decision-making.

Decision Making based on a Continuum of Care

Everyone knows that even before facility commissioning is complete, healthcare facilities are being adjusted, because of last minute changes. For example, a new surgeon is hired months before the facility opens, and requires a clustered instead of the previously planned linear surgical suite configuration. Everyone also knows that facilities will continue to be transformed in small and large ways, over many years, because of changing organizational priorities, shifting demographics, new medical practices and technologies, and insurance policies.

Our research finds that while the concept of "life-cycle" assessment is popular, it is poorly defined and seldom applied with rigor. Our studies indicate that the concept of "continuum of care" may be more appropriate, and should apply not only to the people whose health these facilities are designed to recover and enhance, but to healthcare facilities themselves. This suggests that the current focus on near-term planning, budgeting, funding, design, construction, commissioning and outfitting of facilities – despite claims of "life-cycle" management – must be supplanted by a longer view of continuous transformation. This long view must then be supported by scenario planning and cost modeling, and by data collection necessary for evaluating the return on investment of long-term change-accommodation strategies. [10]

"Facilities maintenance" may therefore not be an adequate concept or term of reference for the realities facing healthcare facility clients. More "open ended" and "continuous improvement" attitudes and methods of budgeting, accounting and management are needed, if clients expect their facilities to be sustainable and to provide continuous operational and physical performance.

The Open Building decision model that our research recommends is now conventional in the commercial real estate markets internationally. This may seem unusual because commercial real estate decision-makers are considered to have very short-term interests, being focused on quick profits and turn-around, and aversion to risk. Perhaps because of these tendencies investors have learned to be very "agile" in their decision-making. They have learned to decouple decisions regarding long-term infrastructure elements of their facilities (often called "base buildings") from those elements that change more frequently (often called "fit-out"). This decision model is also evident in large infrastructure planning and operations, such as highways (highways are decoupled from the vehicles using them)[11] and utility systems, in which electrical power transmission lines are designed with the capacity to accommodate a range of (changing) downstream user demands controlled by independent agents.

Decoupling Based on Use-Life of Systems

As already noted, conventional acquisition methods assume that all relevant information for a facility be aggregated (often called "integrated") at once, at the beginning of the acquisition process. It is assumed that a budget can only be fixed in this way.

In contrast, an Open Building decision-making process requires implementation of a serial decision-making model. This model is based on the principle of decoupling parts of a facility having long term utility from the parts having shorter-term utility. This model is partly in use by some clients in the United States and Europe. For example, our research found that the US Department of Defense Health Agency uses a separate acquisition contract called "Initial Outfitting and Transition" (IO&T) to manage the specification and acquisition of equipment, information technology and furnishings of its health care assets. Similarly, the use of "incremental funding waivers" in fast-track projects now allows funding of, for example, an early "foundation package" even before detailed design of the rest of the building is complete.

The "Open Building" serial decision-making model has three "system levels":

Primary System: Base Building – an "open building": structure, skin and primary (unchangeable) mechanical, electrical and plumbing systems – expected to have a 100 year life (Figure 1);

Secondary System: Fit-out – all components and spaces directly supporting functionality, including the parts of the mechanical, electrical and plumbing systems specific to a given program of functions – expected to have a 10-30 year useful life;

Tertiary System: Furnishings, fixtures and equipment – short-term investments such as equipment, furnishings, IT systems and consumables – expected to change rapidly, in 1-5 years.[12]

Design decision-making for facilities should be decoupled based on the expected lifecycle (use-value) of the system "level" concerned. That is, it must be possible for the tertiary system to change without (excessive) disruption of the secondary system; and the secondary system (representing evolving client mission, functional and space requirements) must be able to change without disrupting the primary system.

Therefore, building elements and spaces with an expected long life should be strictly and explicitly decoupled from building elements and spaces with shorter expected use lives. This decoupling must be implemented in all phases including the planning, budgeting, design and construction (and renovation) processes.

The reason for decoupling is to assure that the change of a building element with a short life (e.g. an element serving a specific function) does not require disruption or change (or only minimal change quickly accomplished) of an element with an expected long life (i.e. an element or configuration that supports many building functions). For example, changing a wall with an expected short life should not require demolishing the structure; changing an electrical outlet should not require demolishing the wall it follows.

Within each of the three "systems levels" (Primary, Secondary, Tertiary), it is possible to find "fixed" and "variable" parts. For instance, the facade is assigned to the primary system. But within the "facade" category, some parts may need to be replaced or upgraded more frequently than other parts (e.g. windows may need to be replaced before the entire building cladding comes due for replacement; in that case, the building envelope as such is "fixed" and the windows are "variable") (Figure 2, Figure 3).

It Is of the Utmost Importance to Get the Primary System Right

This imperative is not unlike the necessary importance placed on getting the urban transportation and public space structure "right", because it sets the stage for 100+ years of evolution of the urban fabric. In that case, the street corridors and public parks together constitute a "fixed" configuration, while the public utilities that circulate in or under these public spaces, and the various and changing uses of these spaces, are "variable".

For similar reasons, the greatest emphasis must be placed on primary system longevity (and energy efficiency) in the face of inevitable functional and operational evolution in healthcare. The primary system should be built to offer long-term utility value to society, the client and the character of the urban fabric it is part of. This means that the primary system planning cannot be allowed to be dependent only on current knowledge, preferences and data.

This is the first and most important decoupling and is the most difficult to implement in an organizational culture used to operating with a model of unified top-down control in which all parts are equally dependent on all other parts. Therefore, most of the recommended flexibility requirements focus on getting the primary system "right", and getting it decoupled from the secondary system.

Fluidity of the Secondary and Tertiary Systems

International research shows that the state-of-the-art in secondary systems (mirroring evolving functional requirements, medical practices, etc.) and tertiary systems (constituting the movable equipment now undergoing the most rapid evolution and miniaturization) for medical facilities is already well on its way to the needed flexibility (decoupling). For example, comprehensive healthcare "systems" offered by large vendors such as Herman Miller and Steelcase (to name just two) illustrate the extent to which the boundary between secondary and tertiary systems is being blurred: walls, equipment and some MEP systems components are being bundled, with interfaces resolved within the "product" of one provider – often patent protected. These interfaces are not as well understood, when different companies deliver and install elements of attempted "integrated" solutions.

In the "open market", the interfaces between secondary and tertiary systems that must be solved on-site are very much in flux, as evidenced by a careful reading of IO&T contracts (Initial Outfitting and Transition – equivalent in large measure to the Tertiary System). In these contracts, interdependencies between these two levels are repeatedly indicated and are repeatedly the source of problems: quality control, re-work, and litigation over the locus of responsibility.

Further work is needed to develop smart requirements for the secondary and tertiary systems. This will also require further consideration of interfaces "on" and "between" system levels in products and components offered in the "open" market (now international). An example of an interface "on" a level is the interface between electrical cable distribution and walls "on" the secondary system level is quite problematic and needs work. New solutions are available but their introduction can be disruptive to conventional arrangements between stakeholders who do not want to change their habits or supply chain relationships.

An example of an interface "between" levels is the electrical cabling at the primary system level and the secondary system, and between secondary system (walls) and tertiary system (equipment).

The development of performance-based flexibility requirements for such interfaces (and there are many) requires a separate research effort.

From Integrated to Serial Decision Making

Translating the decoupling principle in Figure 3 into an acquisition-sequencing model, the recommended "serial" sequence (bottom sequence Figure 4 below) is actually an evolution of the recently implemented separation of IO&T (Initial Outfitting and Transition) contracts used in the US Department of Defense Health Agency (shown in the middle diagram in Figure 4 below).

The principle understanding embodied in a serial decision-making sequence (for new construction and for comprehensive reactivation of existing facilities) is that all facts and requirements cannot be known at once – at the beginning of a many-decades-long process from decision-to-build/renovate, through acquisition of funds, planning, construction, commissioning, move-in and later adaptation to new requirements.

Decisions are inescapably made sequentially – and by different design teams and facility leadership teams – from initial acquisition and then continuously over the life of the facility. It could not be otherwise.

Basic Open Building Requirements

A comprehensive examination of best practices in health care facilities worldwide leads to the following high-level Open Building requirements:[10] Site Capacity for expansion (including site infrastructure, parking, etc); Building expansion capacity (vertical and/or horizontal); Geometry of the structural system (simple and regular geometry is usually better); Natural light (a necessity in many codes for all habitable spaces); Floor-to-Floor Height Requirement (large enough for horizontal installations); Loading Capacity of Floors (to accommodate a sensible range of equipment loads); Minimal Internal Structural Walls (or if internal bearing walls are needed, they are positioned following a capacity analysis); Flexible Facades (facades should be removable without disturbing the primary system's structure); System Separation based on expected use-value (to make building adaptation efficient and to reduce conflict, both technical and social, when parts change); Layout and MEP flexibility for the Secondary System (since the secondary system corresponds to uses and floor plan configurations, mechanical, electrical and plumbing systems must be given space for deployment within the Primary System); Opportunity for Vertical Mechanical Equipment in the Future (our research found that almost without exception, new functional requirements necessitated additional vertical MEP shafts); Multifunctional layout of rooms (as many rooms as possible should be capable of accommodating a variety of uses and equipment); Capacity for Variable Inpatient Bedroom Sizes (debates continue as to the criticality of single vs semi-private patient rooms; therefore the Primary system should be designed to accommodate both).

Implementing Open Building through Design Submittals

Design submittal requirements are often used by clients to instruct architects and engineers in the preparation of drawings and specifications at each mandated design submission: Conceptual, Schematic, Design Development and so on. Open Building implementation necessities that architects and engineers explicitly demonstrate how they are complying with the requirements, and the client must monitor compliance. This means that Design Submittal requirements must be very clear in stipulating what level of detail is needed at each submittal in demonstrating both spatial and installation change-accommodation. That is, Primary System drawings (both architectural and mechanical systems) must clearly show what range of variations are possible in the Secondary System, and so on.

Design Submittals required of architects and engineers must be periodically assessed and revised. The client must develop the methods, skills and culture to update these requirements as experience is gained and maintain vigilance of compliance over time in.

Requirements for High Performance and Sustainability

Leading health care clients are now attempting to achieve high performance and sustainable infrastructure and facilities. This is the existing mandate across all U.S. Federal Government agencies and is increasingly mandated industry-wide.

The next step is to explicitly link the Open Building mandate to "sustainability" mandates. Movement in this direction is already evident. For example, the LEED v4 for Building Design and Construction (Leadership in Energy and Environmental Design) includes a section pertaining to "design for flexibility" applied to healthcare facilities with the following intent: "Conserve resources associated with the construction and management of buildings by designing for flexibility and ease of future adaptation and for the service life of components and assemblies." V4 also includes LEED BD+C: Core and Shell, which is equivalent generally speaking to Primary System①.

Linking Open Building to Resiliency and Adaptation to Climate Change

Discussions with leading experts and a review of recent literature leads to the conclusion that both resiliency – the ability to withstand and recover from extreme natural and human-caused events – and capacity to adapt to climate change relate strongly to Open Building principles. While the causes of facility change differ (evolving functional and satisfaction factors over time drive the need for Open Building) the common required facility performance has to do with reducing the ripple effects of change in one part of a facility to all parts of that facility or installation.

In decision-making for resiliency and adaptation to climate change, an economic and political (social/organizational/behavioral) assessment is required to evaluate the efficacy and return on investment of implementing resiliency strategies. The same assessment is needed in preparing a facility for capacity to adapt to changes in medical practices and so on. That is, if Open Building is achieved, resilience and capacity to adapt to climate change are easier to achieve. That said, some of the recommended Open Building strategies noted above are demonstrably more relevant in achieving resiliency and climate change adaptability than others.

As an example, Cambridge University and Loughborough University in the UK are engaged in developing strategies for upgrading existing healthcare facilities to accommodate climate change (e.g. rising ambient temperature), focusing on energy systems upgrades that will not increase energy budgets. An Open Building facility using several of the strategies we recommend would go a long way to supporting such upgrading②.

Linking Flexibility and Sustainable Buildings – Moving Beyond Technique

Up to now, the discourse on high performance and sustainable buildings – in published technical reports, academic and industry conferences, in client organizations and among service providers – has been largely devoid of a fundamental rethinking of decision-making patterns. The discourse has focused on technique. Discussion about technique is preferred because of its presumed scientific objectivity and purported grounding in technical rationality.

Discussions about decision-making control, on the other hand, inevitably encounter questions of the distribution of control (no single person can control everything in a complex infrastructure system), for which there are no "right" answers that can be justified by technical rationality. The literature (von Hippel at MIT) also calls this "task partitioning".[13] Organizations steeped in the culture of technical rationality, but who also must inescapably operate in complex patterns of distributed control, do not have good theory on which to establish policy and practices linking technique and control: thus the avoidance of systematic restructuring of decision-making. This difficulty is particularly evident in a large governmental organizations that have grown larger over time and which have tended to accumulate patterns of decision-making, with few opportunities for a thorough overhaul.

What is common across these cases our research examined is that a hierarchy of interests exists. At the highest level are interests in the long-term survival and maintenance of the asset base. In the case Federal level agencies in the United States, it is the US Congress. They are, in theory, concerned about the long-term public interests. On the other end of the hierarchy of interests are doctors and other caregivers. They are the direct service providers and are ethically and professionally committed to offering the best care with the best medicine, technology and personnel.

A model may explain which system level is most appropriately paired with "interests":

Primary System → Central Organization (Agency, Governing Board)
Secondary System → Local Healthcare Facility Management Group
Tertiary System → Doctors and Nurses

A Shift of Perspective Is Required

As noted in the introduction, both clients and design service providers for the most part remain tied to 20th century concepts of built environment, rooted in functionalism. This is itself rooted in scientific rationalism, which, in respect to the making of built environment, suggests that with enough research, correct – and largely timeless – specifications can be developed regarding human behavior and needed physical environment attributes. As noted in our research, however, this view is at odds with the reality that built environment is in almost constant transformation. Further, new knowledge gives new answers to human preferences and aspirations, making old assumptions obsolete.

Our research therefore suggests that a shift of perspective is required:

Assets understood as static → Assets understood as subject to transformation

Decision making focused on the initial acquisition of an asset → Decision making over time (assets will be transformed over time)

Flexibility focused on technology → Flexibility focused on sequenced decision-making over the life of the facility
Flexibility separated from sustainability → Flexibility Enabling sustainability
Flexibility as an option → Flexibility as a requirement

Conclusions and Recommendations for Further Actions

Everyone knows that healthy built environment changes to accommodate varied and evolving inhabitation and use. Everyone knows that we face ever larger and fast-paced projects – from the urban scale to the fine-grain work of building renovation – that require skillful distribution of design responsibility. Sustainability shows us the importance of avoiding waste, forcing us to separate building elements based on their different lifespans.

Our research has focused on the shortcomings of current decision making processes and the needed shift to an infrastructure model of the built environment. We have also observed a general trend apparent in various kinds of real estate assets – including but not limited to healthcare facilities – that can be understood as the emergence of a new kind of infrastructure. This trend is the result of forces in society across the world that are not new but that are slowly but clearly altering the way we deal with buildings. It may be safe to assume that these forces – toward larger projects, more obvious patterns of change, and increasing availability of sophisticated equipment and utility services – will not go away. Therefore, we suggest that the emergence of buildings as infrastructure invites clear recognition and active development of open building. The resulting impacts on real estate development and architecture, including healthcare facilities, will be significant.

The problems to be faced in pursuing these goals are not trivial. Necessary professional reorientation (including architectural and engineering education) and changes in management and accounting may well determine the pace, direction and quality of change. But it is important to note that the shifts in perspective pointed out in our research have emerged from sound economic reasoning and a willingness to respond to market forces. The time may have come to establish a more explicit platform for study and development of what seems to have come not as a new design idea, but as a reality to be taken seriously.

A New Imperative

How did it become normal that all buildings must be designed to resist fires? How did it become normal that natural light and ventilation would be required in all habitable rooms; or that all buildings must conserve energy?

These requirements became normal because society learned to understand these standards to be part of the common good – what is good for everyone, both individually and collectively.

For a time, there was resistance to these standards; their adoption meant that people had to change their habits, methods and even attitudes. The charge was made that applying these standards would cost more, which it probably did. But after a while, everyone came to believe that these standards were good and should be required. The history of built environment is evidence of this inexorable tendency to raise standards in the building stock.

Now, sustainability is (almost) normal. Almost everyone agrees now that making a building sustainable – even net-zero – will save money and resources in the long run and therefore should become ordinary. In fact, sustainability was never an issue in historic cities, which changed part-by-part and lasted for millennia in a dynamic balance with resources and social norms. Now sustainability, after much effort, has, like fire-protection, become an explicit imperative that few will argue with.

It's time for open building in healthcare facility design and planning to become ordinary – an imperative just as ubiquitous as fire resistive construction and sustainability.

注释

①详见LEED官网http://www.usgbc.org/LEED。

②引自Slaughter Sarah的*Building it Better: Making Our Infrastructure Sustainable and Disaster Resilient*一文，详见http://mitsloan.mit.edu/newsroom/2007-slaughter.php. 2007。

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作者简介：史蒂芬 · 肯德尔　美国鲍尔州立大学教授

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