

ISA: Precedent Studies in Arch Structures III

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Abstract

Engaging structures as impetus for architectural design, this paper examines the implementation of an approach to precedent analysis -- the ISA -- within an architectural structures course. As a means to graft the knowledge digested into familiar design languages, this pedagogy frames the precedent work in three perspectives: First, an understanding of the designers' intent through assigned readings, essays, and in-class discussions; Second, computational modeling of structural components utilizing Revit's *Adaptive Families*; and finally, a comparative analysis of the impact of formal variations on the structural efficacy through diagramming load-path and lateral resistance. Selected for their passion regarding structural logic, the semester spans a wide breadth of structural considerations through three paramount engineers; Eugene Viollet-le-Duc, Eladio Dieste, and Peter Rice. Aiming to develop a strong relationship between structural logic and architectural design decisions, the ISA approach weaves an understanding of the designers Intent (I) through the readings, Skills learning (S) within Autodesk Revit, and Analysis (A) documented in diagrams.

In Transition

This paper presents an architectural structures III course developed for a "one-time" transitional moment within an architectural curriculum. This course was charged with segueing an understanding of structural logic back into architectural design thinking for a group of fourth and fifth-year B.Arch and 2nd year M.Arch students who recently completed two semesters of structures

coursework instructed by faculty in the Construction Management department. Questioning how structures coursework can best influence students' design decisions in their studio work, the selection of precedent analysis and more specifically the methods one uses to understand the design decisions of past work, became the foundation for this pedagogy.

Following two semesters of structures instruction where isolated elements remained abstract in their calculations -- unrelated to the design decisions -- this course aimed to draw a direct connection between structural concepts and the experience of architecture. The study of architectural precedent was selected as framework for this course for its ability to address the holistic impact of structural design on completed work. To accomplish this, a series of buildings were selected for the explicit and integral nature of structural concepts to their design. This pedagogy proposes that once structural logic has been tied to the experience, a bridge is built for the students to freely move structural intent into the familiar territory of architectural design decisions.

This paper presents the sequence of assignments, work product, and selective answers from the students' evaluation to critique three key perspectives: firstly, engaging structural logic as a design catalyst; secondly, developing proficiency in modeling and the design exploration of structures through greater computational skills development; and thirdly, the ability to investigate and communicate an understanding of complex structures through analytical diagrams.

ISA: Three Perspectives on Precedents

Engaging structures as impetus for architectural design, this paper examines the implementation of an approach to precedent analysis -- the ISA -- within an architectural structures course. This pedagogy frames the precedent work in three perspectives: First, an understanding of the designers' intent (I) through assigned readings, essays, and in-class discussions; Second, computational modeling of structural (S) components utilizing Revit's *Adaptive Families*; and finally, a comparative analysis (A) of the impact of formal variations on the structural efficacy through diagramming loadpath and lateral resistance. Each of these rely on familiar methods of communication to assist the transition of the newly acquired structural concepts into later design decisions by the students.

Understanding the Designers Intent (I)

More than just assigning chapters, the selected readings expose the students to passionate, responsive, and most importantly the inquisitive reasoning for challenging structural standards in construction. The goal of selecting these three specific readings from -- Viollet-le-Duc, Eladio Dieste, and Peter Rice -- is to give the students precedent for making arguments for "why structure can, and in some cases should, take the lead in design investigations".

Student Evaluations:

The readings were perhaps my favorite part of the course assignments. As opposed to the vast majority of readings I have received so far in architecture school, the assigned writings were refreshingly succinct, clear, and demonstrative of solid ideas and understanding from the authors. - Anonymous M.Arch 2020

The readings assigned first helped to frame the specific principles being explored in each project, while class discussions then emphasized key aspects of the architects' and engineers' goals. - Anonymous M.Arch 2020

Building Computational Skills (S)

The computational modeling of each building element within Revit's *Adaptive Family* components demands the students 'construct' a digital model for each building element of the precedent projects. Unlike Rhino, 3dMax, Blender, or Maya, the *Generic Model Adaptive* components in Revit demand the creation of a catalog of individually modeled digital files. These files act much like a hardware store stocked with unique and variable building materials. The students complete the course having developed a collection of various details, structural members, and approaches to long-spans that form a constellation of structural assemblies. The students walk away with the confidence to utilize this catalog of components in their future design work.

Student Evaluations:

By utilizing Revit and building in adaptive components, we had the opportunity to experience first-hand how modifying one element may come to affect another in the overall system, and so on. Having the ability to recreate these components and assemblies, piece-by-piece, and create a library of families with which to pull from in the future really helped to understand how each of the parts came together to work as a unified whole in each related system. - Anonymous M.Arch 2020

The digital modeling was quite challenging with my having had virtually no revit experience. The value of adaptive components in the world of box plug-and-play architecture became quickly apparent. - Anonymous M.Arch 2020

The ability to explore structural principles through 3D modelling forced me to understand individual components, assembly methods, and finally, how the assemblies distribute forces and resist lateral stresses and loads... I felt I was learning from multiple fronts—both structural understanding and new, useful and relevant modeling skills in Revit. The ability to put components together correctly displays a higher understanding of building principles than simple reiteration, verbally or written, of the same principles. - Anonymous M.Arch 2020

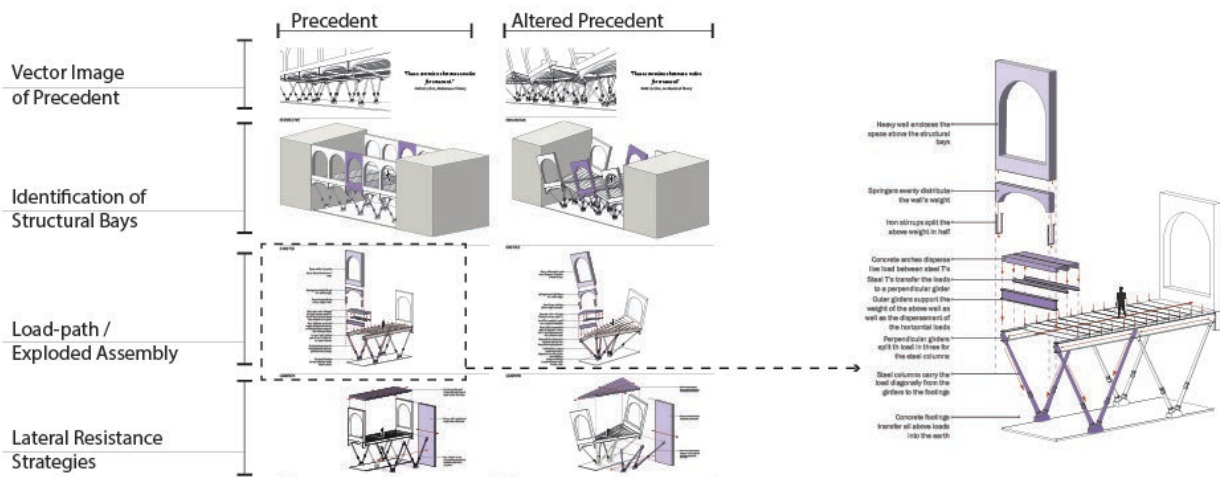


fig. 01 Viollet-le-Duc: C. Crane B.Arch 2020

Analysis through Diagramming (A)

Once the components are modeled and the precedent projects 'assembled' in Revit, the students ability to quickly export vector-based, isometric drawings shifts the course towards the diagramming of structural concepts. The use of isometric drawings to diagram load-paths, lateral forces, and assembly relationships strengthen the analytical communication skills the students have acquired in their design studios. In addition to analyzing the precedent, the students are asked to utilize the adaptive nature of the components to stretch, twist, and antagonize the precedents' structural logic. Once adjusted and diagrammed again, the class is able to discuss where the structural forces may have been altered. This additional step moves the assignment into design decisions by the student and closer to integration into studio work.

Student Evaluations:

The diagramming of forces was easily the point of the process where I learned the most. I found the learning was equally dependent on the the explanations given in the lectures as well as on my first attempts at diagramming on my own. The diagramming of forces gave me a firmer grasp on the designers' thinking, not only in what they did, but the specific reasons and how they came to those solutions. - Anonymous M.Arch 2020

Being able to show how these forces were affected graphically rather than numerically is extremely useful for explaining compound assemblies to someone who may not quite have the grasp on the physics at work in the proposed building. The analysis of such complex structures requires a basic knowledge of forces that had been buried by two semesters of mine dulling math. - Anonymous B.Arch 2020

The methodology implemented for this class is great and encourage students to expand their way of thinking, interpret, and make diagrams that will be accessible to people that have (may) not be familiar with the project before. - Anonymous B.Arch 2020

Sequencing Concepts and Computational Skills

The course is separated into 3 phases; An introduction into the computer applications, a series of precedent studies, and ending with an independent analysis. The initial three weeks of the course were dedicated to exposing the students to fundamental Revit skills. Although phase one was seeded with a pre-semester dissemination of video tutorials and a reading on Systems Thinking by Donella Meadows, all of the class time was spent introducing benefits of the Watchmakerⁱ modeling logic inherent in Revit's *Generic Model Adaptive Components*.

Phase two of the course, spanning 7 weeks, was separated into three near equal parts. Selected for their passion for structural logic, the semester spans a wide breadth of ideas through three paramount structural designers; Eugene Viollet-le-Duc, Eladio Dieste, and Peter Rice. Their selection facilitated discussions on the role of materials, labor, structural form and cultural identity in the design of structural assemblies. The elegance of the ISA process is in the sequencing of the precedents paired with the growing skills demanded of them in Revit's *Generic Model Adaptive* components. Although listed chronologically, this is merely coincidental. Each Engineer and subsequent projects were selected and ordered to develop a linear relationship between an increased complexity of structural concepts and a greater demand of computational modeling skills.

Starting slowly, two weeks were scheduled to investigate a single project by Viollet-le-Duc -- the unbuilt Marketplace. Picking up the pace, the next two weeks addressed complex structural form with two projects by Eladio Dieste; the Church of Cristo Obrero and the Salto Municipal Bus Terminal. Maintaining the momentum, three weeks were dedicated to investigating three projects by Peter Rice; the tensile curtain wall system at Les Serres & Cité des Sciences et de l'Industrie, the gerberettes of Centre Georges Pompidou, and culminating with the complexity of Padre Pio Pilgrimage Church in San Giovanni Rotondo.

Initially, the final phase of the course was scheduled for the student to take this newly acquired skill set to document and assess their current studio project. A mid-semester assessment of the pace of the course demanded this proposed work product be replaced with the development of an annotated catalog of the students work.

Targeted ISA Lessons

Viollet-le-Duc

Drawing from selected chapters of *The Architectural Theory of Viollet-Le-Duc: Reading and Commentary* (1990), I found the students initially skeptical of a 19th century text's relevance in a contemporary advanced structures course. By throwing the students directly into Chapter 5, Handling Materials, students found they could relate to Viollet-le-Duc's clear respect and interest for materials. Class discussions broached Viollet-le-Duc legacy, specifically regarding his impact on countless architects, and urban planners, who espouse how they too have found inspiration from his words. In Chapter 6, Planning Rationally, Viollet-le-Duc's drive for "Structural Honesty" and "The Ills of Irrational Design" establishes a clear language for the students to question the precedent projects to come.

Sample Student Writing Assignment:

Chapter 5 states, "Materials should be employed in a manner constant with the formulation of a structure. Their proper use contributes to the clarity of structural expression; their misuse, on the other hand, diminishes the effectiveness of a design." This is a rather important note to take away as aspiring architects. Understanding the viable construct-ability of our own designs is a rather powerful tool. When you understand the beautiful, intricate work put into these structures it becomes repulsive to cover it with a facade as many designers do today.
- xx B.Arch '20

It is logical to build and design based on the capabilities of the material, be it the way iron can be molded or the compressive qualities of stone. These principles can be observed as carrying through the future to Louis Kahn's impassioned speech articulating the proper use of material. Le Duc and Kahn both knew that one must not only honor the material, but also in a way that showcases the capabilities of that particular material. - xx M.Arch 2020

The Marketplace, although unrealized, initiates the courses precedent studies. Viollet-le-Duc's disparate, exterior perspective drawing, building section, and written

description highlight not a cohesive finished design, but instead stresses key structural ideas. First, the angled columns are discussed for three structural concepts; They are knuckled to decrease their slenderness ratio and in-turn increasing their resistance to bending while sloped; The angles of the columns are equal and opposite with a loadbearing girder above resisting the tension caused by the outward thrust; and, the un-equally loaded columns demands a single foundation to maintain uniform settlement for each pair. In addition to the column system, Viollet-le-Duc's exploration of iron in the floor diaphragm's framing exhibits the beginning of today's composite construction -- steel decking with concrete. The students document the inverted structural "T" which maximizes the extreme tensile fibers while establishing bearing for the solid stone blocks acting in compression.

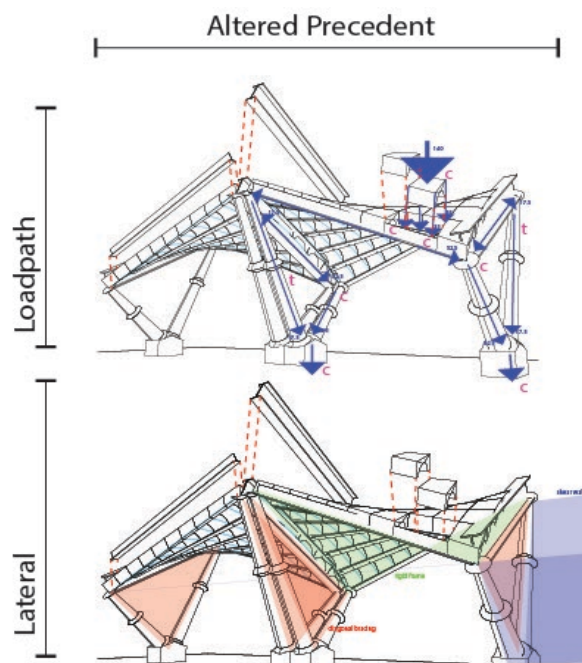


Fig. 02 Viollet-le-Duc: A. Hussain M.Arch 2020

The Marketplaces' structural assembly -- column, girder, beams, joist, and flooring -- set the stage for the oldest of the precedent projects selected to demonstrate the potential future use of the individual components created

in Revit, but more importantly, act as an accessible introduction to the design potential of parametric qualities of the *Generic Model Adaptive* components. Within Revit's Family types, the *Generic Model* was utilized familiar sweep and revolve commands to model detail connection elements like column caps and bases. More complex parametric variables are introduced with the *Generic Models Adaptive* families when modeling the column and beam members. *Generic Model Pattern Based* exposed the students to the divide surface command and the nesting ability of surface patterns.

Eladio Dieste

The English Summary from Eladio Dieste *La Estructura Ceramica* (1987) moves the course away from Viollet-le-Duc's fixation on the identity of individual structural elements and towards labor and structural form. By elevating the act of construction -- both the sequence of, and those responsible for -- Eladio Dieste demonstrates the fruitfulness of a cohesiveness approach to material, technique, and humanity in his theory of Cosmic Economy. Eladio Dieste's self-consciousness regarding his lack of formal architectural education, highlights his reliance on the understanding of fundamental yet nearly inconceivable structural logic. Dieste's concern for the "tyranny of the drawing board" and his contempt for modern architectural practice's fixation on the quantifiable plan drawings, directly opposes the students' architectural education. In his essay, "Art, the People, and Technocracy," students are exposed to alternate priorities, such as the roll of labor and embodied knowledge with a field of craftsmanship that are the catalyst for his work.

Sample Student Writing Assignment:

Dieste is convinced that construction of buildings has the possibility to be animated and meaningful. The production and composition of the materials of a building should not merely be a skeleton in which the façade is tacked on later; rather the structure itself should show and actually be the eloquence of the architecture. He states, "For architecture to be truly constructed,

the materials must be used with profound respect for their essence and possibilities.” In other words, the architecture should not be defined by decorative designs; the materiality and structural makeup of the building should express it. He further reiterates this point when he states, “Coherence between the form and the constructed reality is also very significant (193).” Form should be informed by structure. - xx M.Arch ‘20

In Eladio Dieste 1943-1996, the architect and engineer addresses the importance of responsible and rational thinking of an architect in selecting building and construction methods. He states, “A sound and sensible architecture requires the rational and economic use of construction materials.” Being from Uruguay, a developing country, the realities of domestic economy, technology, and industry must be intrinsic considerations in the design of architecture. Put simply, if the means are not feasible, the method is wrong. - xx M.Arch ‘20

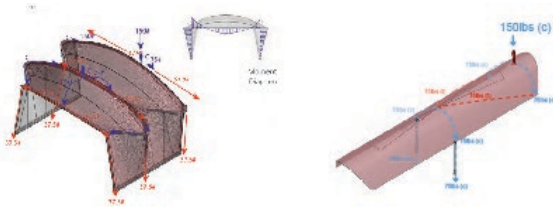


fig. 03 Dieste: B. Bailey M.Arch 2020

Moving beyond the nested assembly in Viollet-le-Duc's Market, the two projects by Eladio Dieste were selected for their clear demonstration of the integral strength of well-conceived structural forms. Discussions of Thomas Jefferson's single wythe serpentine walls at Monticello, ground an initial understanding of the complex shear and moment strength created in Dieste's undulating wall and roof connections in the Church of Cristo Obrero. Further investigation into Dieste's gaussian vaults demonstrate a sophisticated manipulation of simple catenary forces. The second precedent, the Salto Municipal Bus Terminal, like several other of Diestes cantilevered vaults makes use of a nearly imperceptibly double wythe assembly. Although balanced with an immense span, the students become keenly aware of the lack of required lateral resistance in the later example.

When modeling the structural form of Dieste's Church of Cristo Obrero, nesting and offsetting *Control Points* on *Reference Lines* created complex forms that segue directly into Revit *Project* wall and roof types. The addition of instance parameters on the offset dimensions of the *Reference Lines* establishes a parametric logic for the sine-wave form of the church's wall and roof. When challenged by the Salto Municipal Bus Terminal, the students set width to span ratios for vaults, along with symmetrical expansion of cantilevers. By nesting *Reference Splines* into *Divided Surfaces*, the complex tensile system of structural rebar would respond to parametric variations within the arch and cantilevers.

Peter Rice

Within the first pages of *An Engineer Imagines*, Peter Rice's excitement for the expression of structure is palpable as he drops the reader into the design process for one of his most recognized works, Centre George Pompidou. Rice's work, specifically the trusses' at Les Serres, the gerberettes at the Pompidou, and the stone arches at Padre Pio, are the culmination of both Viollet-le-Duc's concern for materials and integrity and Dieste's elevation of the act of construction and structural form. Exposure to Peter Rice passion for elevating the expression of structure, moves the ideas represented in earlier precedents into contemporary and relatable architectural projects.

Sample Student Writing Assignment:

Rice's mentality is shown when he says, "We had built the Sydney Opera House after all, I was the living proof, and now we had to deliver." It is the subtle determination in this quote that shows how much focus Rice puts into his work, and how through this focus he brings to life the true value of the projects he works on. His determination is also shown in his consideration for the use of cast steel. - xx M.Arch 2020

The journey through the conception and construction of the Pompidou by Peter Rice in An Engineer Imagines reveals a strong adherence to its design intent, through the team's decision making process, choice of materials, choice of forms,

and all the hardships in between. This emphasis on an expressive joint reflected their original theoretical wish for the building to be culturally friendly to all people, open and classless.

- xx M.Arch 2020

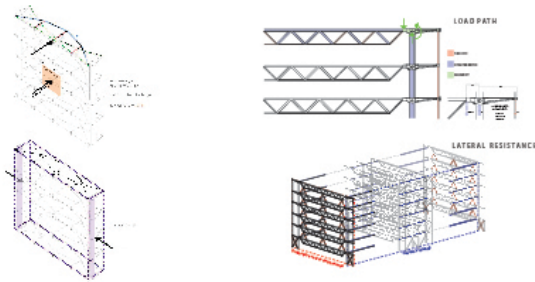


fig. Peter Rice: B.Smith M.Arch 2020

The three final precedent projects were selected to move the structural ideas discussed into contemporary construction. Beginning with the trusses designed for the glass facades at Les Serres & Cité des Sciences et de l'Industrie, the students are exposed to a common structural concept, that of an open web steel truss, refined to respond to a more complex, multi-axis loading. Through the diagramming of the mirrored tensile chord members within the trusses, the students identify how the newly formed offset axis of these tensile members eliminates the need for out-of-plane bracing -- forces highlighted by an expressive photo of Peter hanging from an unsupported 'bottom' chord. Following, the Centre Georges Pompidou demands the students to decipher a network of complex relationships. The pin-connections used throughout the structural scaffolding of the Pompidou, demand that the individual structural members be recognized and modeled for their tensile or compressive forces. Having completed the reading, the students have insight into the design decisions motivating the use of back spanning gerberettes -- maximizing clear spans while minimizing truss depth. A holistic assessment of lateral forces focuses the students on the unique vertical x-bracing connections between trusses on the short North and South facades.

The course ends with an investigation into Padre Pio Pilgrimage Church. Although Peter Rice passed before this project was completed (he is noted as the conceptual designer) this building brings a culmination of the lessons touched upon in the semester. A floating Roof-Diaphragm, angled 'V' metal riser connections, multiple non-uniform loading on catenary stone arches set in a lateral resisting radial all culminate in terrifying foundations responding to the immense thrust.

No additional modeling skills are required for this final series of projects. Rather the complex logic of structural relationships in each demand that the students develop additional 'parameters' in their *Generic Model Adaptive* components. In each, these variables are nested from one file into the next, computationally constructing the structural logic of the precedent work.

Constructive Criticism + Conclusion

Although this course was developed for a unique moment of curricular change, it's success and a current opportunity for redevelopment of our structures sequence, leads to speculation on how this ISA approach may resurface in the development of future courses. Reflecting on the student work and evaluations, I feel a few changes are necessary to the pace of the course and greater clarity brought to the introduction of the computational skillsets.

Student Evaluations:

I understand the 'pros' of using Revit for this course, however, it was overwhelming to learn a new software so quickly, while also facing the deadlines for each project to be completed. - Anonymous

I think the adaptive model portion wasn't quite as useful and should be replaced with something more focused on structure. - Anonymous

The course began a little haptic; however, the corrective actions taken to steer the course in the right direction about halfway

through the semester proved to enhance the course work and experience overall. Although many seemed to complain about the heavy Revit Emphasis -- I found it to be an incredibly beneficial experience and found the skillset that was built through these exercises really was the best way to understand the complexities of the structures. - Anonymous

I think with a more stringent set of expectations of what is expected out of Revit could help push students to utilize the resources that the instructor is offering. Also, the projects that were created in class were all extremely complex. If one of the projects was less complex and explored more common understanding the foothold needed for the course could have been strengthened. - Anonymous

With a 77% response rate of this 30-student course, the student evaluations identified two areas of concern. First, a collection of students made note of the difficulty of learning Revit in tandem with the course content. For context, early within our curriculum, we have a course dedicated to learning basic computational programs (Adobe suite, Rhino...). Although a few students felt they should have a separate course to be 'taught' these skills, I believe the imbedding of tutorials within the course curriculum is beneficial. If instructed again, I would dedicate more energy in the first three weeks to developing the students' fundamental skills in Revit and Illustrator to facilitate the learning outcomes of the later work. A second critique, questions the selection of Revit over a structural analysis program. With my professional practice, teaching experience, and considering the

Notes:

1 Dieste, Eladio. "Eladio Dieste : La Estructura Cerámica. Bogotá" Colombia : Diseño y edición, Escala, 1987. Print

2 Meadows, Donella H. "Thinking In Systems: a Primer" London; Sterling, VA: Earthscan, 2009. Print.

average student's work product from this course, I have found that Revit's *Generic Model Adaptive* components can act as a unique lynchpin between understanding the structural logic of assemblies and facilitating creative design exploration and communication.

When considering the three goals of the ISA pedagogy, the first, engaging structural logic as a design catalyst, the student essays effectively demonstrate a clear appreciation for the role that various structural ideas played in the precedent projects. Achieving the second goal of developing proficiency in the computational modeling and design exploration of structures, proved to be the most challenging. The student work product parallels the evaluations with approximately a third of the class never becoming facile with the program. With regards to the final goal, success in the development of the students' ability to investigate and communicate an understanding of complex structures is explicit in the students' graphic work submitted and reflections in the course evaluations. The ability to communicate clearly, through familiar graphic diagramming strategies, set a stage of for in-class discussions of complex course material.

Considering these outcomes -- with the aforementioned adjustments -- I feel the ISA approach to precedent analysis is an effective bridge between structure course content and a nascent architecture designer's studio work.

3 Rice, Peter. "An Engineer Imagines" London: Artemis, 1994. Print.

4 Viollet-le-Duc, Eugène-Emmanuel, and M. F. Hearn. "The Architectural Theory of Viollet-Le-Duc: Readings and Commentary" Cambridge, MA: MIT Press, 1990. Print.

ⁱ A fable of two equally skilled watchmakers. The first works on a single watch diligently from beginning to end. The second, develops sub-systems, so unlike the first, does not have to

restart when disrupted. The quality remains but efficiency increases.