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Birth of the Construction Triangular Theorem

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Introduction

A successful construction project entails teamwork, coordination and organization. Construction as a whole is a complex sequential process. This process involves various stakeholders and trade professionals to establish a profound project. In order to be more specific on the topic, the word “Project” will be used extensively throughout the paper. The practice of Architecture is one of the main pillars in achieving a successful construction project. Architecture lays the framework and foundation in constructing any building. Engineering is one of the 3 main prerequisites in achieving a structurally well built project in a well built environment, without compromising life safety. Simultaneously, project management is one of the final practices to achieve a successful construction project.

The thesis statement for this dissertation is as followed: *“In order for a construction project to be successful, professionals must engage in the practice and ideology of the Construction Triangle, which involves proper architectural practice, engineering due diligence and mastering the art of project management principles.”* This thesis will elaborate on all key components; architectural practice, design and implementation, engineering practice, specializing in structural engineering and lastly, project management principles, focusing on project organization including scope, time and cost. All these disciplines will consequently result in the birth and ideology of the

Construction Triangle, where the disciplines of Architecture, Engineering and Project Management all come together to formulate this theorem.

There will be numerous publications being cited throughout the Thesis Dissertation. Chiefly, one of the key scholars noted in the thesis is Ruth Slavid, the author of “10 Principles of Architecture,” where Slavid talks about the role of the Architect and how Architecture plays a vital role in our society. In other words, we will explore Slavid’s understanding of Architecture and see how his ideas will eventually tie in with the successful output of the Construction Triangle.

Another key scholar mentioned is Marco Bussagli, the Author of “Understanding Architecture, Volume 2,” where he brings us back as early as 1418 and discusses the work of Filippo Brunelleschi, among others, who was a notable Architect, Engineer and Builder. At the same time, Bussagli reminds us about the key ‘players’ in the role of Architecture and Engineering during the Renaissance and Bascillican era, which has influenced the respective professions today. For this reason, we will analyze Bussagli’s relations with both Architecture and Engineering and see how his ideas play a big part in this theorem.

In addition, one of the last key sources used is the “Project Management Book of Knowledge (PMBOK)”, by the Project Management Institute. This book is a universal book on project management principles, where it also acts as a guide for all professionals in fields such as IT, Finance, Banking, Engineering, Architecture, Construction, etc. All things considered, we will explore how these principles act as a foundation for any successful construction project. In addition, we will also explore

Cynthia Stackpole Snyder's, "A User's Manual to the PMBOK Guide- Fifth Edition," and use excerpts and quotes from her book in order to gain a clear understanding on the various knowledge areas and how they related to construction.

Finally, we will explore the birth of the Construction Triangle. The Construction Triangle looks exactly what it sounds like; a triangle or pyramid. Like the Pythagoras theorem, this concept is similar. However, it is not similar in the sense that this theory is mathematical. The thesis statement insinuating Architecture, Engineering and Project Management as being one of the three main pillars for a successful construction output will be proven. There will be an in depth analysis on the study of Architecture and its contributing factors to the theorem. Later on, we will dissect the study of Engineering and focus primarily on Structural Engineering, among other engineering disciplines and see how this discipline will play a sequential, yet pivotal role in construction. With this in mind, project management will complete the triangular theorem by virtues of exploring how scope, time and cost acts as an essential element and tool in establishing a good project. Although we will briefly touch upon other project management principles, scope, time and cost will be our prime focus throughout the dissertation. It is by virtue of the above analysis, the theory will be proved.

The paper will then exemplify an overview of the topic and there will be an analysis depicting how the Construction Triangular Theorem will have a profound impact on not only the community we live in but also the world. Even though the dissertation focuses on the built environment specifically, it will unleash how this Construction Triangular Theorem will make sense in our day to day construction practices and operation, which consequently results in a positive community.

Architectural Practice and Design

Architecture is a discipline that requires precision and critical thinking. Architectural design starts off with a blank slate. As the client's needs and requests become more specific, the slate becomes more detailed with design. Architecture involves continuous coordination between trades and stakeholders. Architecture is one of the three prerequisites in formulating a successful construction project.

Ruth Slavid's book "10 Principles of Architecture" reiterates all facets of architecture, specifically the role of architecture and engineering. Slavid (2012) starts off with a complex statement: "the charm of the conceit lay in the incongruity of using an approach intended to convey the complexity of a building to present something that most of us can produce without recourse to any drawings at all (Slavid, 2012, 9)." Slavid is insinuating that the idea of a design concept is not so simple. There are many complexities in a design concept that must be captured before any drawings can be produced. This is essential in architecture because communication is vital. Once this sort of complexity is overcome, we can then move on to the schematic designs.

This is also essential in construction because this step lays a foundation for future design ideas and concepts. Slavid (2012) also talks about the role of the Architect: "Any Architect who is working on a preliminary design of a building has to juggle with everything from disposition of spaces and the appearance of the facades to the height of the stair treads and the layout of the bathrooms to say the very least"

(Slavid, 2012,10). Slavid (2012) does an excellent job communicating the complexities each Architect faces in their day to day function. This concept of “juggling” that Slavid (2012) mentions is a metaphor for coordinating between all facets of a design. Right away it becomes apparent that the field of architecture involves a sequential process and requires critical thinking. Since the Architect is the mastermind behind the design, he/she must ensure that all the information is present, which is why Slavid (2012) mentions: “But it is traditionally the Architect who pulls all the ideas and documents together to create the design of the building, just so the Architect will know enough about the topics to at least ask any questions necessary” (Slavid, 2012, p. 11). This step is crucial. Once all questions are answered, this can act as a guide throughout the design process. Schematic designs can easily turn into working drawings once all pertinent questions are answered and all construction documents such as Permits are all applied for.

If we fast track for a moment, Slavid (2012) mentions how structure plays a major role in Architectural practice. As a matter of fact, Slavid (2012) has a full chapter on structure, which ties in with this field. Salvid (2012) talks about the viability of today’s built environment: He quotes, “Generous spaces, rational plans, durable materials and a design that allows elements that will wear out or become outdated to be altered easily are the nearest we can get guarantee that today’s buildings will be viable tomorrow and well in to the future” (Slavid, 2013, 64). Slavid (2012) is reiterating that in order for a building to be well sustained, space, plans and proper construction material must be selected. This idea is key because sustainability plays a big role in built environments as Slavid (2012) depicts in his following statement: “In some cases, sustainability factors are concerned with the health of people using the building, with designers avoiding any materials that give off volatile gases that could affect in particular, the very young and those with allergies or breathing difficulties" (Slavid, 2013, 90). Health and safety is one of the most utmost priorities and foremost duties for Architects. Architects have a responsibility to ensure that public safety and interest comes first, like any other regulated profession.

All architectural association licensing bodies across the world have at least one commonality, to protect public safety. The Ontario Association of Architects (OAA) in Canada has such a mandate: "The association is dedicated to promoting and increasing the knowledge, skill and proficiency of its members and administering the Architects Act, in order that the public interest be served and protected" (OAA). The association further adds that "Ontario Architects are highly trained professionals bound by regulations made under the Architects Act" (OAA). This is essential because the "Architects Act" serves as a guide for regulatory procedures for the Practice of Architecture in the province of Ontario (Architects Act). The regulation is reiterating that Architects have a duty under the regulation and practice itself to serve the public's interest. This is partly why professionals such as Architects and Engineers must hold a Certificate of Practice and mandatory professional liability insurance in order to practice.

Slavid (2012) points out that "landscape has a part to play (in architecture) as well. It does not have to be the traditional path between planted areas, but could instead be a change of colour or of texture" (Slavid, 2012, 110). Slavid (2012) is insinuating that landscape is indeed a component of architecture, but not a critical focal point in architectural design. Landscape architecture is beneficial for curb appeal and to some extent the environment, however, it does not play a role in built environments such as building design and construction. We will predominately focus on concrete block and brick construction. Slavid (2012) touches upon the topics of acoustical engineering, especially in today's day and age. He says: "Acoustic engineering is a well-respected discipline with the cleverest acoustic engineers producing some superb spaces for performances. Any surface will either reflect a sound or absorb it, or diffuse it" (Slavid, 2012, 144). Slavid (2012) then uses an example of a ball: "If the ball is hard and shiny, the ball will bounce off (reflection). If it is soft and giving, the ball will just tumble off (absorption). And if it is rough, the ball will probably bounce off but in an unpredictable direction (diffusion)" (Slavid, 2012, 144). Acoustic engineering is also important because like landscape architecture, acoustical engineering is also another component of architecture. This type of science involves specialized engineers to perform complex calculations. Once again, this is another coordination scenario between the Architect and the various trade consultants.

Another notable author is Marco Bussagli who wrote, "Understanding Architecture." Bussagli's (2004) approach was to analyze architecture in a sequential format, where there are timelines throughout this book. One of the most prominent figures discussed in his book was Fillipo Brunelleschi. Bussagli (2004) talks about how Brunelleschi came up with the rules of perspectives and how he uses mathematics and physics to implement these rules. "This led to his famous ideals for proportional harmony (Bussagli, 2004, 286)." One of the buildings noted in Brunelleschi's work was the San Lorenzo in the 15th century. This is interesting because centuries later, the idea and science of proportional harmony is still evident today. Without proportional harmony, there wouldn't be any proper engineering and architectural proportions. This is important because this concept is what Architecture and Engineering is all about.

Bussagli (2004) also touches upon the Florence Cathedral, in which Brunelleschi was the Engineer and Architect for the dome design and construction. Bussagli (2004) says that "the problem of the Florence Cathedral was constructing a dome without resorting to fixed eternal centering to support the masonry. Brunelleschi managed to solve the problem by following the Roman technique of layering the bricks in a fishbone pattern, which made them self-bearing" (Bussagli, 2004, 287). This is a genius idea by Brunelleschi. During the Renaissance period, there was no such profession as an Architect or an Engineer. They were both considered one in the same thing. For an Engineer to even create a design of a dome was a brilliant idea at the time and even today. Based on his principles for creating the dome, design professionals are following the same concept today. As a matter of fact, there are design softwares today that work off of proportional harmony. Such softwares are AutoCAD, a software used as a computer tool for design and engineering purposes. Of course the software has enhanced beyond belief, but to imagine that Brunelleschi used calculations and design elements that is so complex, is unimaginable.

Another notable author presented is Mr. Steward Brand, the writer of "How Buildings Learn; What Happens After They're Built." Brand (1994) talks about a topic on "Shearing Layers" on Chapter 2 of his book, known as the "Six S's, oriented towards interior work, known as the Sheary Layers of Change by Frank Duffy. There will be commentary on each "S" component after Duffy's following six "S's" are clearly defined.

For the first part, Duffy talks about "Site, where this is the geographical setting, the urban location, and the legally defined lot, whose boundaries and context outlast generations of ephemeral building; site is eternal. Structure is the foundation and load-bearing which are perilous and expensive to change. These are the buildings. Structural life ranges from 30 to 300 years (But few buildings make it past 60, for other reasons). Then Duffy talks about Skin and says that the exterior surfaces now change away 20 years or so, to keep up with fashion and technology, or for wholesale repair. Recent focus on energy costs has led to re-engineered skins that are air-tight and better insulated. Then Duffy moves on to the topic of Services and says that these are the working guts of a building communications wiring, electrical wiring, plumbing, sprinkler system, HVAC, and moving parts like elevators and escalators. They wear out and obsolesce every 7 to 15 years. Many buildings are demolished early if their outdated systems are too deeply embedded to replace easily. The fifth "S" that Duffy reiterates is Space Plan. The interior layout- where walls, ceilings, floors, and doors go. Turbulent commercial space can change every 3 years or so; exceptionally quiet homes might wait 30 years. Finally Duffy concludes by his final "S", Stuff. Chairs, desks, phones, pictures kitchen appliances, lamps, hair brushes; all the things that twitch around daily to monthly. Furniture is called mobilia in Italian for a good reason" (Brand, 1994, 13).

When Duffy talks about site, the geographical location is indeed very crucial in any building element, whether it be design, construction, or even market research. Duffy is right in saying that this "urban location" will outlast for generations.

In terms of Structure, Duffy pinpoints the typical structural component of the building, which is the foundation. He mentions that the foundations and load bearing elements are imminent to danger and risk, which is why people don’t consider changes in this element. When load-bearing elements are altered, there is a need for a building permit application because this sort of element, like other elements such as plumbing and HVAC, are prone to liability, which is why the authorities having jurisdiction require a professional such as an Engineer or Architect to engage in this sort of practice.

Duffy then recounts the idea of Skin. This is interesting because in this day and age, the skin is referred to as the building envelope. Duffy mentions how the “skin” needs to be up-to-date with fashion and technology. As well, there is in fact recent focus on energy costs, which lead owners to re-engineer the facades or building envelope as a whole. This idea saves costs in terms of heat loss, and insulation barriers.

Duffy brings up the elements of Services, where he focuses on any electrical, communicative and mechanical components of a building. He calls this the working “guts” of a building, which is more or less an accurate depiction and analogy compared to the human anatomy. The wiring, mechanical systems, such as the elevators, escalators and such make up the anatomy of a building. This is essential because this is also an operations and maintenance component which every building must have.

Duffy then explains the whole concept of space planning. He talks about the interior components of a building such as the walls, floors and ceilings and mentions how commercial properties are prone to change the interior layout on average every 3 years or so, whereas residential buildings can last as long as 30 years. His theory in this context is two-fold. It is true that a commercial place of business could be prone to changing their space planning techniques every 3 years, but there could be a chance they may not. A medical office, for example, may find it beneficial to leave their interior elements as an institutional feel as the practitioners may want patients to understand that this place is a place of medical care and wellness. Duffy's account on residential properties is also debatable. He does mention a home being renovated as long as 30 years, but does not mention how there may be an indecisive home owner renovating their home every 6 months for example, especially in today's world.

Lastly, Duffy talks about an informal account on "stuff." It appears that "stuff" refers to the furniture, fixtures and equipment (FF+E). This is somewhat similar to the "services" aspect of one of Duffy's "S" components in the sense that it may be anatomical. Wiring and cabling, as well as the use of an elevator are an operational feature for a building. Whereas a component of FF+E such as chair or a desk also serves as an operational feature because it is consistent with a day to day operational use. Another example that Duffy describes is a lamp. A lamp is clearly an operational tool that office professionals use every day.

One may ask how all the above authors and their theories of Architecture all result in a successful construction project. Before anyone can justify this question, we have to look deep into the science and art of Architecture. Slavid (2012) had clearly stated the complexity of Architecture. For example, he mentions the design element of Architecture along with the "juggling" and coordination between trades. So design and coordination is one of the essential elements of architecture which leads to a successful construction project. Second, Slavid (2012) talks about the viability of the built environments along with public safety, consequently leading up to the Architect's responsibility as a design professional. The viability of Architecture is important in

Architecture because without this, construction would turn into turmoil. The Architect's foremost duty above everything is to ensure public safety is not compromised. This entails the Architect to design with precision and ensure that all load-bearing calculations are fully coordinated with all consultants including the Structural Engineer. This makes up for a successful construction project. A final topic touched upon was acoustical engineering and the idea of reflection and absorption. This is a common element in architectural design. Once again this involves coordination between the Architect and the Acoustical Engineer.

Marco Bussagli (2004) mentions the work of one of the most influential leaders in Architecture and Engineering, Fillipo Brunelleschi. His idea on proportional harmony is what makes architecture today. This sort of practice satisfies a successful construction practice because the design and construction of any building must be proportional in order to be viable.

Lastly, Steward Brand (1994) mentions Frank Duffy's six "S's"; site, structure, skin, service, space planning and stuff. Although these elements of architecture are informal, they are nonetheless accurate. Whereas the site being the geographical location, the structure being the foundation and the load-bearing elements, the skin being the exterior facade, service being the anatomical components such as wiring, space planning focusing primarily on interior design and finally the idea of stuff, which act as the furniture, fixtures and equipment of a building. All these "S" components make up a successful project because each and every element is what makes a proper built environment.

Engineering Due Diligence

Like architecture, engineering involves critical thinking and logic. Although both disciplines were the same at one point, such as Fillipo Brunelleschi's era, the actual sciences of these two fields differ by virtue of the following: Architecture involves creativity and feasibility, whereas engineering however, involves rationality, problem solving and technical and theoretical calculations. This is why these two fields of study will be treated as separate entities.

One of the first most prominent authors discussed is also Ruth Slavid (2012), among many other great scholars. In Slavid's "10 Principles in Architecture", he discusses the actual standing structure of architecture: "The single most important consideration about buildings is that they should stand up- and should continue standing in all the circumstances which they are likely to encounter...a whole profession, that of the structural engineer, exists to prevent such disasters" (Slavid, 2012, 39). He then adds that "buildings need to withstand both static loads and dynamic loads (Slavid, 2012, 39)." If a building is not structurally intact, then that building is prone to disaster, which will result in liability claims. A standing structure is one of the main prerequisites in architecture and structural engineering. If the building tends to be flimsy and not appear to be structurally sound, then the Structural Engineer did not do his/her job correctly.

However, there is a precondition for the standing structure and this is the foundation. Slavid (2012) writes: “Getting the foundation right is vital and is the subject of an entire discipline, known as ‘ground engineering.’ It is essential to understand not only the loads and home they are applied to, but also the physical properties of the soil” (Slavid, 2012, 41). This is vital in foundation design. Professionals such as Geotechnical Engineers and soil specialists must determine the sustainability of the earth’s soil to determine if it is in fact feasible to construct a foundation. One of the biggest questions asked is “what is a foundation?” According to Wikipedia, “a foundation is the lowest and supporting layer of a structure, where the foundation is divided into two categories: shallow foundations and deep foundations.”

The definition here is very simple. A deep foundation is for structures that withhold a greater mass such as a high rise building or an institution such as a hospital. A shallow foundation is intended for a smaller scale structure such as a house or low rise building. In this regard, the foundation would in fact withhold both static and dynamic loads as Slavid (2012) describes it.

Slavid (2012) then adds that “the fundamental calculations to work out the structural requirements on buildings have not changed over the centuries, but the tools that are available to do so have developed enormously, and this has had an impact on the kind of structures that it is possible to design” (Slavid, 2012, 41). One example is the design software, AutoCAD, as mentioned in the previous topic on architecture. If we look at Brunelleschi’s Florence Cathedral in Italy, the dome was a very complex design because it required complex calculations. One must be a mathematical genius to design something so difficult in practice. If this sort of dome were to be constructed today, the technology and most up to date design software would make it more quick and efficient. One does not necessarily have to be a mathematician to do the design, but should have knowledge on structures and design. The structural engineer's role is to analyze the structural compounds and elements used in design, in addition to the complex calculations.

Slavid (2012) then adds, "that the best projects do not consist of an imaginative design that the Architect then heads to the structural engineer, saying 'make this work for me'. Instead, they are collaboration, with both architect and structural engineer contributing along with other consultants. In this way, it is possible to achieve the most economical structure- which in a pleasing piece of synergy, is likely to be the most elegant and the least expensive" (Slavid, 2012, 49). Slavid (2012) is correct in saying how the Architect and the Structural Engineer must collaborate to ensure an economical output. What Slavid (2012) means is that if both professionals were working together from the beginning, there would not have to be the going back and forth with each other. The initial collaboration saves time and money for all parties. If there were any issues, it would have been addressed during the schematic design phase, or even the working drawing phase. The Architect must design in accordance with the Engineer's calculations related to load. Likewise, the engineer has to perform his/her calculations in accordance to the design. As stated earlier, the structural feasibility of the materials need to be assessed by the engineer during the working drawings phase.

On a final point by Slavid (2012), he mentions how "just as good architects and structural engineers collaborate on a design, so too there should be collaboration between the architect and the services manager" (Slavid, 2012, 73). He is making a point that there has to be proper coordination between all trades and not just with the Structural Engineer. When there is proper and open communication with all stakeholders, the process of design and construction becomes more efficient and easier.

Andrea Deplazes talks about a detailed account on masonry bonds in his book, “Constructing Architecture; Materials Processes Structures.” Deplazes (2010) will explain his 8 points on masonry bonds, calling it the principles of masonry bonds. There will then be commentary on each principle. “*The principles of masonry bonds apply only to a bond consisting of manmade masonry units; i.e. Clay, calcium silicate, concrete bricks, or blocks.*

1) *Exactly horizontal courses of masonry units are the prerequisites for a proper masonry bond.*
2) *Stretcher and header courses should alternate regularly on elevation.*
3) *There should be as many headers as possible in the core of every envy course.*
4) *There should be as many whole bricks or blocks as possible and only as many bats as necessary to produce the bond (3/4 bats at corners and ends to avoid continuous vertical joints).*
5) *As far as possible, the perpends in each course should continue straight through the full thickness of the masonry.*
6) *The perpends of two successive course should be offset by ¼ to ½ of the length of a masonry unit and should never coincide.*

7) *At the corners, intersection and butt joints of masonry components, the stretcher courses should always continue through uninterrupted, whereas the header courses can form a straight joint.*
8) *At an internal corner the perpends in successive courses must be offset.*

Numerous variations can be produced according to the principles of masonry bonds; indeed as interesting derivations based on the following logic: the length of a masonry unit is equal to twice its width plus one perpend (e.g. 29= 14+14+1)" (Deplazes, 2010, 36).

Deplazes' (2010) reiterates a very good technique in masonry bonds. First, Deplazes (2010) talks about how effective masonry bonds should be laid horizontally to get the maximum load capacity as well. Then he mentions how as the elevation increases, the stretcher and header portion of the bricks should alternate. This looks like a sort of criss-cross fashion which is also used in hardwood and laminate flooring. It is recommended that the planks do not align perfectly as these joints may break up in the near future. It should be laid and applied in a criss-cross motion to increase the strength. There is then the mention of how there should be as many headers as possible. The more bricks there are, the better the strength and load of any load-bearing structure or even non-load bearing structures. Deplazes (2010) then made an interesting account on how there should be as many whole bricks or blocks as possible and only as many bats as necessary to produce the bond. According to Dictionary.com, a bat is a brick cut transversely so as to leave one end whole. More whole bricks are better than less whole bricks.

As a matter of fact, more whole bricks are better than header bricks because the bond is better with stretcher bonds and bricks that are applied over this bond. Deplazes (2010) says how the brick pattern should continue straight through the full thickness of the masonry. This is true because any even perpends could compromise the structure. The perpends should be straight to avoid irregularities and structural mishaps. Deplazes (2010) brings up the idea of offsetting, by ¼ to ½ of the length of a masonry unit. This is the basic principle of masonry construction. Finally, Deplazes (2010) talks about each corner, joint and butt connection, making it clear that stretcher connections should continue straight uninterrupted. This appears to be redundant with section 5 because it exemplifies the uniformity of masonry construction. Deplazes (2010) uses a calculative formula to lay bricks and says that the length of the masonry unit is equal to twice its width plus one perpend.

Although the topic of masonry bonds was discussed, the thought of steel structures was not covered. Deplazes (2010) says that “on the other hand, modern construction would hardly be conceivable without steel; on the other, the reasons for using steel- above all as the basis for a design –are not so obvious” (Deplazes, 2010, 113). This is true because steel construction has become an epidemic in today’s construction. Wood beam construction was the popular construction method, but it is now scarce because steel construction is more durable and structurally sound.

The type of steel beams that Deplazes (2010) talks about is I-Beams specifically. He mentions that “*the load-bearing structure consists of a two-way frame with columns made from structural hollow sections which, in contrast to I-Sections (I-Beams), present the same connection options on all sides. As the columns are continuous, beams can* *be connected at any height, which permits different ceiling heights in different bays. To ensure that all floor beams are loaded equally, the direction of span of the floors should change from bay to bay (Deplazes, 2010, 130)."*

This is an interesting topic in structural engineering. Deplazes (2010) now shifts on to the world of structural steel technology and talks about the art of jointing. This is one of the advantages of structural steel construction. Steel has the capability of joining when exposed with a specific heat temperature. Wood joists, however, does not join if exposed with heat. The only way to join is through bolts. Steel has various point loads, especially I-Beams.

One may ask how all these theories and points on Structural Engineering result in a successful construction project. The first thing we have to realize is the role of the Structural Engineer. Structural Engineers take calculated risks every day. Their role, like Architects, is to ensure that public safety is not compromised. They ensure this by virtue of their design. The role of safety for engineers is one notch higher than Architects. The reason for this is because a lot of the engineers' job is to perform complex calculations on point load and structural integrity. Slavid (2012) talks about the foundation and how this piece of construction is essential. Without the foundation, the building would not be able to stand. The foundation will be carrying the entire load. Second, Slavid (2012) mentions calculations. Today's technological softwares such as AutoCAD have made designing and construction much easier. Although complex calculations still exist, CAD softwares make the process less tedious. The third notion that Slavid (2012) mentions are the idea of collaboration. This idea is key because the situation is "catch 22."

Without Engineers, Architects cannot do their jobs. And without Architectural designs, the engineer cannot do his/her job.

Deplazes (2010) then explains the idea of masonry bonds which is very interesting in construction. It is indeed self explanatory why the art of masonry bond is a pivotal tool in the built environment and is therefore crucial in achieving a successful construction project. As a start, masonry bonds act as shelter against any catastrophic nature and protection in general. Getting the art of masonry jointing correct ensures structural integrity, which consequently results in a successful output. If this process is not done properly, we are prone to failure as a result of disaster. Deplazes (2010) finally talks about the steel construction and how this is the most up to date and viable technology in construction today. Steel materials such as I-beams have the capability of jointing when exposed to a certain temperature. This enables precision and proportion in constructing a building. Furthermore, this practice ensures a successful construction output when done properly.

Project Management Principles

Project Management is the art of bringing stakeholders together and completing a project within scope, time and budget. This discipline involves strong communication with all stakeholders, along with enhanced scheduling. The overall scope of a project is a big factor in determining the project's parameters and extent of work. Timing is crucial, especially when coordinating between trades and consultants. Finally the budget and cost factors play an extremely significant role in project management. Cost and budget determine everything for a project, from standard kitchen cabinets, for example, to high end cabinets. Cost becomes a factor, timing become a factor and the scope changes. All faucets of project management are crucial in a successful construction project.

There will be references used from the PMI's "The Project Management Body of Knowledge (PMBOK)". PMI is an abbreviation for the Project Management Institute in which they call themselves the authors for PMBOK. After each reference, there will be commentary to assess each point. According to PMI (2007), they define a project as "being a temporary endeavor undertaken to create a unique product, service, or result. The end is reached when the project's objectives have been achieved or when the project is terminated because its objectives will not be met or cannot be met or when the need for the project no longer exists" (PMI, 2007, 5). This is a very good definition because all factors in project management is covered is somewhat broad. The PMI (2007) further adds that "project management is the application of knowledge, skills, tools and techniques to project activities to meet the project requirements" (PMI, 2007, 6). We will get back to this definition more towards the end of the dissertation to see how this ties in with the notion that effective project management results in a successful construction project.

The PMI (2007) states that 'the PMBOK Guide is the standard for managing most projects most of the time across many types of industries. This standard describes the project management processes, tools, and techniques used to manage a project towards a successful outcome" (PMI, 2007, 13). This is the exact reason why the PMBOK guide was chosen as the book for this discussion; it acts as a standard for all disciplines. The PMI (2007) further adds that "the standard is unique to the project management field and has interrelationships to other project management disciplines" (PMI, 2007, 13). This proves that project management is uniform and branches out in various disciplines such as Architecture, banking, Finance, IT, Construction, Engineering, etc. For the sake of argument, we will be focusing primarily with construction project management.

Before we get started on analyzing the three most vital processes in project management, we must understand what the role of the Project Manager is. PMI (2007) indicated that "*a Project Manager must be able to understand project detail, but manage from the overall project perspective. As the person responsible for the success of the project, a project manager is in charge of all aspects of the project including, but not limited to:*

- *Developing the project management plan and all related component plans.*
- *Keeping the project on track in terms of schedule and budget.*
- *Identifying, monitoring and responding to risk, and*
- *Providing accurate and timely reporting of project managers" (PMI, 2010, 26).*

The project manager is one of the final leaders responsible for the success of a project, as stipulated by the PMI (2007). This means their role is highly responsible and lucrative at times. Their role involves evaluating scope, proper scheduling and accurate budgeting. This idea leads to the three most vital anatomical roles in project management; Scope, Time and Cost (STC). After discussing "scope, time and cost," we will further discuss the next collaborated project management processes: integration, quality, human resources, communications, risk, procurement and stakeholder management.

Project Scope Management

According to the PMI (2007), *"project scope management includes the processes required to ensure that the project includes all the work required, and only the work required, to complete the job successfully. Managing the project scope is primarily concerned with defining and controlling what is and is not included in the project:*

1) *Collect Requirements – The process of defining and documenting stakeholders' needs to meet the project objectives*
2) *Define Scope – The process of developing a detailed description of the project and product.*
3) *Create a WBS- The process of sub-dividing project deliverables and project work into smaller, more manageable components.*
4) *Verify Scope – The process of formalizing acceptance of the completed project deliverables.*
5) *Control Scope – The process of monitoring the status of the project and product scope and managing changes to the topic" (PMI, 2007, 103).*

In a nutshell, the project's objectives have to be laid on the table. This process is a means to an end, where we gather the info, dissect it and finally manage it. The PMI (2007) refers to scope as

a) collecting requirements, where the project manager gathers the information and most importantly, the objective of the project from notable stakeholders, such as the client or project sponsor
b) where the project manager is expected to define the scope of the project itself,

c) Where the project manager is expected to create a Work Breakdown Structure (WBS) and literally breakdown each component of the project. An example could be defining the role of a Drywaller, where this tradesman has sub-trades working under their control, such as tapers, plasterers, or perhaps painters. Each professional has a role to play in the project and has a set of responsibilities to achieve on time and within budget.

d) The project manager is responsible for receiving sign offs from key stakeholders on the final decisions made throughout the initial phases of design or even construction.

e) Finally the Project Manager is expected to be in full control of the scope once all approvals have been met. This includes overseeing the project and taking control and managing any changes throughout the project.

Before we conclude Project Scope Management, we are going to go in depth with the characteristics of the Work Breakdown Structure (WBS), just so we all have a clear understanding on how this structure plays an eminent role in defining a scope of any given project. The PMBOK Guide stipulates that “the Work Breakdown Structure (WBS) is a deliverable-oriented hierarchical decomposition of the work to be executed by the project team to accomplish the project objectives and create the required deliverables, with each descending level of the WBS representing an increasingly detailed definition of the project work and the WBS organizes and defines the total scope of the project, and represents the work specified in the current approved project scope statement” (PMI, 2007,116). As briefly stated earlier, an example was used for a Drywaller and his sub-trades. Now we’ll use a more complex macro-level example. The WBS starts off with a central topic or objective.

If we use the example of a hospital construction project, the central topic will be “Hospital Construction.” This topic is broken down in multi-facets, where the first example being the Architect. The Architect has categories such as schematic design, CAD Operations, Working Drawings, Permits, Approvals, etc. Each category can be broken down into sub-categories and each sub-category can be broken down into multiple sub-categories and so on. The next example is the role of the Engineer. Once again, this category is staggered into sub-categories such as mechanical engineering, structural engineering, load calculations, feasibility studies and much more. Furthermore, the WBS lays a crucial foundation for brainstorming key components of a project.

Project Time Management

Project Time Management is such a constituent element in Project Management. As designated in the PMBOK Guide, “*project time management includes the processes* *required to manage timely completion of the project. Project Time Management processes:*

1.1) Define Activities – The process of identifying the specific actions to be performed to produce the project deliverables.

1.2) Sequence Activities – The process of identifying and documenting relationships among the project activities.

1.3) Estimate Activity Resources – The process of estimating the type and quantities of material, people, equipment, or supplies required to perform each activity.

1.4) Estimate Activity Durations – The process of approximately the number of work periods needed to complete individual activities with estimated resources.

1.5) Develop Schedule – The process of analyzing activity sequences, durations, resource requirements, and schedule constraints to create the project schedule.

1.6) Control Schedule – The process of monitoring the status of the project to update project progress, and managing changes to the schedule baseline" (PMI, 2007, 129).

Project Time Management is indeed complex. If we look at each activity, it tries to be as specific as possible. The first being defining the activities. This is the initial component of time management because it involves identifying specific items to produce a successful output. This leads to the idea of sequencing the activities, where we determine commonalities between project activities. Following this, the Project Manager is expected to estimate the activity resources whereby he/she has to quantify the materials and equipment, trades, etc. Essentially, this is where all the resources are evaluated.

Then the PMBOK Guide talks about estimating activity durations where each work period is calculated for each task. This becomes more specific because each trade, for example, has a certain amount of hours they can work on a specific task. Finally, the guide talks about developing a schedule. This is one of the major milestones that determine the forecast of the project. Last, but not least, the Project Manager has control over the schedule. This is exactly what it sounds like. The Project Manager has full control of the schedule in the sense that he/she does intensive monitoring, updating and noting changes, including key milestones throughout the project life cycle.

The PMI (2007) presses on one of the above line items, “develop schedule.” The Guide mentions how “entering the activities durations, and resources into the scheduling tool generates a schedule with planned dates for completing project activities” (PMI, 2007, 152). This is interesting because every activity has a chain reaction. For example, if we bring back the idea of the hospital project, the “Foundations” sub-category in the category of Construction management must be completed first in order to start framing. Relating this back to schedule development and activity duration, there must be an approximate set of hours for each trade before we can schedule another trade.

Project Cost Management

One of the last most profound elements of Project Management is Project Cost Management. Cost is a major factor in any project-related activity. The PMI (2007) defines Project Cost Management as being *the "processes involved in estimating, budgeting, and controlling costs so that the project can be completed within the approved budget: 3 main Project Cost Management processes which include:*

2.1) Estimate Costs – The process of developing an approximation of the monetary resources needed to complete project activities.

2.2) Determine Budget - The process of aggregating the estimated costs of individual activities or work packages to establish an authorized cost baseline.

2.3) Control Costs – The process of monitoring the status of the project to update the project budget and managing changes to the cost baseline" (PMI, 2007, 165).

The theoretical components appear to be straightforward and simple, whereas in practice, Project Cost Management is really fragile and lucrative. There is a difference between cost and budget. Project Cost analyzes the actual cost of construction of any given project, whereas project budget focuses on an estimated or even ball-park figure of a project. The PMI (2007) indicates that the first thing a Project Manager must do in Project Cost Management is to estimate costs. This is done by virtue of analyzing and literally estimating the cost of construction by activity durations and schedule development. Once again, the time management aspect of Project Management forecasts the estimated costs associated with this. Based on the estimated costs, it is easier to determine the budget.

Furthermore, this is not an actual figure because the budget can also account for other various items such as contingency allowance, for example. A 10% contingency is an adequate amount to allow for, for budgetary purposes. These are most often unforeseen costs, due to unforeseen site conditions. For example, if a general contractor is commissioned to relocate an existing wall opening for egress and discovers that the wall is load-bearing after the demolition, then this is classified as an unforeseen site condition, because the allowance of a lintel was not accounted for in the initial estimate, but if a contingency was carried out, then an unforeseen item such as the structural wall could be covered under the cost contract. Lastly, the PMI (2007) reiterates the importance of controlling costs. The Project Manager has to work with a budget and do whatever it takes to ensure that the project is effectively delivered on time and within budget. There are of course change orders throughout the project, ranging from door handles to balcony product changes. Everything is dependent on the client's needs. If the client would like a slightly expensive floor tile for example, the project cost goes up. If the client chooses a slightly cheaper product in price, then the client gets a credit returned from the original stipulated price contract. Furthermore, the Project Manager also acts as the gatekeeper for the budget and provides changes at their own discretion.

If practised correctly, Project Management ensures a successful project when completed. Project Management is the final discipline before the construction of a structure. Project Managers are present from design up until inception. When we analyze scope, we review the overall breakdown of the project. This is simply a question of what needs to be done. When we define the scope, it is easier to understand the meat of the project. If we look at time management, the schedule plays a pivotal role in achieving a successful project.

Each trade's schedule affects another trade's schedule. In other words, each project is dependent on a different project and if this is not scheduled properly, the project can lose focus and consequently become delayed. Cost, like scope and time serve as an important element in construction. Any project would not be possible without taking into account the project cost management. Furthermore, cost is a variable that affects the flow of construction and its output. In light of the above, scope, time and cost are key ingredients in project management, which result in achieving a successful construction project.

Other Project Management Processes

We will now explore the rest of the project management processes and treat them as subsidiary processes to compliment scope, time and cost. After identifying each management process, we will define what these processes are by exploring Cynthia Snyder's book, "A User's Manual To The PMBOK Guide."

Project Integration Management

According to the "The Project Management Body of Knowledge" and Cynthia Snyder's PMBOK Guide, "Project Integration Management includes the processes and activities needed to identify, define, combine, unify and coordinate the processes and project management activities within the project management process groups (Snyder, 2013, 25)." This management process identifies and consolidates all the project management processes and looks at ways to collaborate all the principles.

The first type of integration management technique is “Develop Project Charter,” where this serves as the first initial document. “Develop Project Charter is the process of developing a document that formally authorises the existence of a project and provides the project manager with the authority to apply organizational resources to project activities (Snyder, 2013, 15).” The project charter consists of a series of purposes; the original intention of the project, the description of the project, as well as other high-level information. There are generally (3) signatures that accompany the charter; the customer, sponsor, and project manager. This will act as the official agreement between all parties.

Another form of integration is the Project Management Plan. “The project management plan is the process of defining, preparing, and coordinating all of the subsidiary plans and integrating them into a comprehensive project management plan. A good part of the project management plan is comprised of the subsidiary management plans that are outputs from the various planning process (Snyder, 2013, 26)” This integration process focuses on detailed PM processes and gets further broken down. As well this acts as a game plan for the existing project.

Integration management also focuses on “Directing and Managing Project Work.” This process is exactly what it sounds like, where the Project Manager is responsible for leading the job and executing the Project Management Plan. This is where all the plans are carried out to produce the project’s deliverables (Snyder, 2013, 162)”. Once again, the Project Management plan is somewhat like a guideline and the subsequent processes is where we execute the Project Management Plan. This leads to our next process, known as monitoring and controlling project work, where this is “the process of tracking, reviewing and reporting the progress to meet the performance objectives defined in the project management plan. The monitor and control project work process is concerned with the status of the project overall (Snyder, 2013, 202).”So direct and manage project work is solely related to the management and coordination of the project, and monitor and control project work pertains to the status quo and tracking aspect of the work performance.

One of the last integration processes is “Perform integrated change control.” This differs from the rest because this process only deals with the reviewing and approval of the change orders and the project manager is responsible for the communication to the respective parties, for example, the project sponsor. This process is important because most of the project manager’s time involves communication and the conveyance of the communication is also vital. Snyder (2013) explains, “By performing change control diligently, you can protect the project from scope creep and from finding yourself at the end of your funds, but with work left to do (Snyder, 2013, 206).”

Finally, closing the project concludes not only the integration process, but also the overall project. “Close project or phase is the process of finalizing all activities across all of the project management process groups to formally complete the project or phase (Snyder, 2013, 255).” This is actually a lengthy process because this phase involves closing out the contract, or colloquially saying “closing the books.” Before closing out the project, the Project Manager would require final sign off from the client/sponsor as well as receiving the final payment for the overall project.

Quality Management

Project Quality Management is “the process of identifying quality requirements and/or standards for the project and its deliverables, and documenting how the project will demonstrate compliance with quality requirements (Cynthia, 2013, 101).” Quality management is broken down into two components; perform quality assurance and control quality. Perform quality assurance is “the process of auditing the quality requirements and the results from quality control measurements to ensure appropriate quality standards and operational definitions are used (Cynthia, 2013, 167).”This sort of process looks at standards and actual quality of the product or, in this case, the result. In construction, we look at construction practice standards; if standards are followed precisely, we expect good quality. Control quality is the process of monitoring and recording results of executing the quality activities to assess performance and recommending necessary changes (Cynthia, 2013, 231).” Like “monitor and control project work,” this form of quality management focuses on the results after execution and monitors and tracks the changes.

Plan Human Resource Management

This process is very tricky and has to be analyzed closely. Plan human resources management is “identifying and documenting project roles, responsibilities, required skills, reporting relationships, and creating a staffing management plan (Snyder, 2013, 112).” In theory, this process comes up with the roles and responsibilities and human resource allocation. This sort of human resource management plan has two tenets; acquiring a project team and developing a project team. Acquiring project team is the process of confirming human resource availability and obtaining the team necessary to complete project activities (Snyder, 2013, 173).” So once again this is confirming that the human resources and staff are available and present. However, “Develop Project Team is the process of improving competencies, team interaction and overall team environment to enhance project performance. This process is separate the process on managing the project team because the focus and techniques for developing a team are different than for managing a team. In developing the project team, you are looking to develop individual skills and competencies as well as a functional team environment (Snyder, 2013, 176).” This process emphasizes on performance and competencies of team members after or during project execution. In construction, and any other project, acquiring and developing a team is one of the prerequisites in achieving a successful project. There would not be a project if it were not for human resource management and most importantly, team work.

Project Communications Management

Project Communication is the number one key element in project management. “Project communications management includes the processes required to ensure timely and appropriate planning, collection, creation, distribution, storage, retrieval, management, control, monitoring, and ultimate disposition of project information (Snyder, 2013, 117).” This means it is evident that most of the project manager’s time involves communication. This process is divided into two categories; manage communications and control communications. “Manage communications is the process of creating, collecting, distributing, storing, retrieving, and the ultimate disposition in accordance with the communications management plan. Manage communications occurs from the start of the project to the finish (Snyder, 2013, 187).” This process involves the birth of communication in any project setting, as well as gathering pertinent information about the specific project. “Control communications is the process of monitoring and controlling communications throughout the entire project lifecycle to ensure the information needs of stakeholders are met (Snyder, 2013, 237).” Like other processes, this stage involves monitoring and tracking communications. This can be in a form of a contract, email, letter, work log, phone log, etc. Furthermore, “the control communication process seeks to ensure that the right people are getting the correct information in a timely manner (Snyder, 2013, 237).” The key word here is “stakeholder” and stakeholders are a project manager’s real customers. When all stakeholders are kept in the loop and aware of the situation, the project runs smoothly. Just to reiterate, a stakeholder is anyone involved within a project, and some key stakeholders are the project sponsors as they are responsible for funding the project.

Project Risk Management

Like any project or endeavor, there is risk involved in some form. “Project Risk Management includes the process of conducting risk management planning, identification, analysis, response planning and controlling risk on a project. Because projects are unique in nature, there is much more uncertainty in a project than there is in regular operations. Risk is rooted in uncertainty- the more uncertainty, the more risk (Snyder, 2013, 123).” No matter how effective a project management plan may be, there is always risk associated with any project. If we use a construction project for example, the project manager must allow for unforeseen site conditions. An example can be the idea of snow, when building in the winter. Once snow and ice enter the equation, this commonly slows down the project. Since Project Risk Management is a serious matter, this topic is broken down in Cynthia Snyder’s (2013) Guide in greater detail. First, Snyder talks about ‘plan risk management,’ where this process “defines how to conduct risk management activities for a project and that risk should be determined in the beginning of the project, in order to avoid potential issues (Snyder, 2013, 124).” The second component of risk management is ‘identifying risk,’ where this “determines which risk may affect the project and documenting their characteristics. As the project progresses, new risks are identified, existing risks evolve and change, some risks occur, and some pass without occurring (Snyder, 2013, 129).” This is more so a checklist of possible threats. A SWOT analysis is a good technique to use to identify risks. Following the identification of risks, the project manager must first “perform qualitative risk analysis.” This process outlines the “prioritizing risks for further analysis or action by assessing and combining their probability of occurrence and impact. For projects with a lot of risks, it is important to prioritize the risks to make sure the team is spending time responding the most crucial risks (Snyder, 2013, 134).” In professional practice, the risks should be laid out and targeted for remedy. Some of these risks can be put on the critical path list, and given utmost priority. Another form of risk management analysis is ‘perform quantitative risk analysis.’ This is an interesting form of risk analysis because this form primarily focuses on the cost value associated with each potential risk. “Perform quantitative risk analysis is the process of numerically analyzing the effect of identified risks on overall project objectives. Many of the modelling and simulation techniques used in this process are appropriate for very large projects that have millions of dollars at risk (Snyder, 2013, 138). ” This is one of the biggest reasons why each project should have a contingency allowance.

After taking qualitative and quantitative risk analysis into consideration, the next steps are to plan risk responses. This is where we "develop options and actions to enhance opportunities and to reduce threats to project objectives (Snyder, 2013, 142)." The Project Management Institute refers to 4 types of negative risks and 4 types of positive risks. The 4 types of negative risks are, "avoidance, transfer, mitigation, and acceptance."Avoidance is when a project management plan is being changed to eliminate the possible threat. Transferring the risk is passing the responsibility to someone who is experienced and better able to manage it. Mitigating the risk is trying to reduce the threat as much as possible. Accepting a risk is where one does not do anything to respond to the risk.

The 4 types of positive risks are: Exploitation, sharing, enhance, accept. Exploiting a risk is not any different than avoiding a risk. Sharing a risk is similar to transferring a risk, where this risk is shared with another company or organization. Enhancing a risk is similar to mitigating a risk as this deals with doing whatever it takes to increase the potentiality of the risk. Finally accepting a risk is accepting the situation without doing anything about it.

The final risk process that the Project Management Institute (2007) and Cynthia Snyder (2013) refer to is Control Risks. "Control risk is the process of implementing risk response plans, tracking identified risks, monitoring residual risks, identifying new risks, and evaluating risk process effectiveness throughout the project (Snyder, 2013, 241)." In other words, this is where risk is taken into consideration and a risk response and solution to handling the risk is initiated. After the responses are initiated, these responses are monitored on their effectiveness.

Plan Procurement Management

Every construction project involves procurement management. “Plan procurement management is the process of documenting project procurement decisions, specifying the approach, and identifying potential sellers (Snyder, 2013, 148).” Like any other planning process, plan procurement management involves planning out each phase. An example of this can be planning out the bidders list, and identifying potential sellers. “Project procurement management includes the process necessary to purchase or acquire products, services or results needed from outside the project team (Snyder, 2013, 147).” In construction, procurement can refer to the services of a sub-trade. For example a painter’s services are procured by the general contractor. One of the first procurement strategies is “conducting procurements.” This is the “process of obtaining seller responses, selecting a seller and awarding a contract. This process works in sequence and not simultaneously (Snyder, 2013, 191).” It is important to know that this process has to be in sequence because a contract has to be awarded before a job can start. After receiving the contracts and awarding the job to the successful bidder, the Project Manager’s job is to now “control procurements.” This is the “process of managing procurement relationships, monitoring contract performance, and making changes and corrections as appropriate, this involves coordinating work between vendors and the project and ensuring appropriate payments to the vendors (Snyder, 2013, 245).” This category falls under monitoring the performance of contracts and taking actions to ensure that the procurement of each phase is running smoothly. The final procurement process is “close procurements.” This is the “process of completing each project procurement. Most controls are closed based on completion –

all the work is done as per the contractual agreement (Snyder, 2013, 258).” In a multi-residential construction project, once the project is signed off and an occupancy permit is received and all vendors are paid in full, this would fall under the close procurement category.

Stakeholder Management

Stakeholder management is one of the new additions to the PM processes, introduced by the Project Management Institute in 2013. “Stakeholder Management includes the process required to identify all people or organizations impacted by the project, analyzing stakeholder expectations and impact on the project, and developing appropriate management strategies for effectively engaging stakeholders in project decisions and execution (Snyder, 2013, 157).” Stakeholders are anyone who has a “stake” in the project and has some sort of involvement, whether directly or indirectly. For example, a sub-contractor is a stakeholder in a project because he/she is involved in the project. Another example is the project sponsor. This sort of stakeholder would be involved in a project in two ways; as a client and as a person who is funding the project. The first stakeholder process would be identifying stakeholders. This is essentially identifying all parties involved, whether it is a person, group and organization that could have any impact on any decisions made throughout the project. This is crucial because we must know who our audience is before we start any project. The second Stakeholder management technique is “plan stakeholder management.” This is the “process of developing appropriate management strategies to effectively engage stakeholders in project decisions and execution based on the analysis of their needs, interests, and potential impacts (Snyder, 2013, 157).” Once again, this is a planning stage, and the project manager’s duty is to effectively engage stakeholders in all decisions. This is where the project manager must come up with a plan to execute this process. “Managing stakeholder engagement” is more like executing this process and ensuring that all decisions are communicated to stakeholders. “Manage stakeholder engagement is the process of communicating and working with stakeholders to meet their needs/expectations, address issues as they occur and foster appropriate stakeholder engagement in project activities throughout the project life cycle (Snyder, 2013, 197).” This proves how keeping the client/sponsor/all stakeholders updated on the status quo and any other feedback is crucial. This is where stakeholder management overlaps with project communication management. The last stakeholder management process is “control stakeholder engagement’, where this involves monitoring the relationships of stakeholders and making changes where necessary.

The Construction Triangular Theorem

What does it take to achieve a successful construction project? How is this defined? There are numerous questions as to how a successful construction project is measured and where we draw the line. The process is very simple. The previous topics such as Architecture, Engineering, Project Management and all its components have a common understanding and this understanding is teamwork. Consultants and other stakeholders may not perceive it this way, but the reality is that everyone and every discipline are working as a team to achieve a project completion. In order to achieve a project completion, all stakeholders must fulfill their mandate first. For example, an Architect must complete his/her working drawings with all designs complete before submitting the drawings over to a Mechanical Engineer. The Mechanical Engineer then inputs his/her mechanical elements in the drawings with specifications and submits it back to the Architect so the Architect can then apply for a Building Permit and an HVAC and Plumbing Permit. This sort of convention exemplifies teamwork.

After teamwork is taken into consideration, communication factors are established. Let us use an example of the Project Manager. Once the tender package is created from the Project Manager, he/she sends out the package to all the trades and has them price out separate components of the project. Once the prices are submitted and the job is commissioned, the project manager communicates with all trades in a form of a trades meeting, pre-construction meeting or even a tender walkthrough. Once all communication is gathered, the project manager creates a schedule that illustrates each trade's work schedule. Basically, this is all achieved through proper communication channels.

As indicated earlier, *"In order for a construction project to be successful, professionals must engage in the practice and ideology of the Construction Triangle, which involves proper architectural practice, engineering due diligence and mastering the art of project management principles."* One of the biggest questions is, what is the construction triangle and how is it formed. The construction triangle is essentially a triangle with 3 major disciplines inside the triangle; architecture, engineering and project management. When brought together, these three disciplines exemplify a successful project. One may ask why these 3 fields are limited to achieving a successful project and why other disciplines are not. We have to look at these fields in a broader picture.

The practice of Architecture is broken down to into various compositions. First is design composition. It is the responsibility of the Architect to ensure that a proper conceptual design is presented with various options. As one of our authors, Slavid (2012) puts it, we Architects “Juggle” with all facets of design every day. With this in mind, Architects must engage in critical thinking and adequate communication with all parties. The second composition is coordination between all trades involved in the project. In order to have a successful output, there must be appropriate coordination between all trades. The third composition is public safety. In order to practice architecture, there must be a responsibility to ensure public safety, as stipulated in every regulation. The fourth composition is acoustical engineering. This is one of the elements that are calculated by an Acoustical Engineer beforehand. The engineers examine the idea of absorption and reflection.

The fifth composition is the science of proportional harmony. Proportions are taken into account during the working drawings phase, which fall under the discipline of architecture. Although Brunelleschi was clearly the founding fathers of proportional harmony, his principles and wisdom is practiced even today. More up to date design softwares such as AutoCAD make it convenient for professionals to design with proportional harmony. The sixth composition is shearing layers, as Frank Duffy puts it. He mentions that site, structure, skin, service, space planning and stuff are what define the shearing layers of a building. Furthermore, there are a total of 6 main compositions that act as pillars for a successful project.

If we shift over to Engineering, this practice has many compositions that validate the idea of resulting in a successful project. The first composition in structural engineering is the foundation, like any other building construction. This sort of composition holds the building up, and acts as a footing for the subsequent types of structures that will be applied. This includes the joists, walls, bricks, beams and all load-bearing components. Without this sort of composition, all structural components will be compromised, resulting in an unsuccessful construction deliverable. A second composition to structural engineering is the actual calculations and formulas used to withstand load. Although there are many compositions that withstand load, engineering calculations is one of the main requirements that are conducive to load-bearing elements. The third composition is collaboration. As simple as it may seem, this element is important because there has to be communication between two main professionals; architects and engineers.

The Architect has to communicate the overall layout to the Engineer so the Engineer can prepare structural calculations. There are definitely various engineers involved as well, such as Mechanical Engineers and Electrical Engineers, but for the purposes of built environments, we will be focusing primarily on structural engineering as this sort of practice is part and parcel with Architectural design. This sort of collaboration as Slavid (2012) states is economical. The reason why he says this is economical is because he believes that no time is wasted when there is a direct collaboration between these two consultants. This is true because communication is clear and all questions and concerns are addressed in a timely fashion. This is economical because time is money and the more time you spend on a design, the more the billable hours increase for both parties.

The fourth composition is the application of masonry bonds. Andrea Deplazes (2010) portrays a perfect depiction and instructions on applying masonry bonds. This sort of trade is interesting because it comes a long way. The traditional term for this profession was a brick layer, as it still is in some instances. Masonry bond composition is without a doubt a profound trade and skill, which is still used today. This is why masonry bonding aides is achieving a successful project.

The fifth composition is Structural Steel Framing. The type of structural steel compound analyzed is I-beams. I-Beams act as multiple point loads unlike wood joists, which are out of industry use. Structural steel fabrication has taken the spot light because this is evidently an innovative technological breakthrough. Structural steel has the capability to bond with a specific temperature setting. I-beams, floor joists and load-bearing steel has changed construction practices and improved the efficiency of structural framing. There are 5 compositions that make up for a good project. Furthermore, structural beams have improved construction practices and the implementation leads to successful construction practices.

Finally Project Management is one of the last pillars in achieving a successful construction project. Organization is key once it comes to construction. All trades must be aligned and properly coordinated before implementation. The project manager oversees the construction from the beginning of the design up until the finish of construction. It is crucial that the flow of construction is properly transitioned in order to achieve a successful project. Like the Construction Triangle, there are three primary ideas that improve the practice of project management. In this case we will call them all compositions. Each composition will be broken down into various categories.

The first composition in project management is scope. Scope essentially defines the project. This sort of process provides insight and overall layout of what needs to be done. If this is not defined, there is no clear instruction on the type of work that needs to be done. The best way to organize the scope is through a Work Breakdown Structure (WBS). This process can provide categories and sub-categories of a specific task. This process can lead to a structured layout and eventually lead to project scheduling where the project manager has a better forecast on project activities.

The second composition is time management. As indicated, the WBS can act as a guide to kick start the scheduling. After defining each activity, there is a sequential process where the project manager, at some instances, has to prove an estimated timeframe of completion based on the documents given. Each sequence is a chain reaction to one another. Moreover, time management influences all aspects of construction.

Finally, the final composition stated is cost management. Like compositions like scope and time, cost management is also a major factor in construction project management. Before any project is started or even accrued, there has to be budgets sets in place. Budgets determine scope and budgets determine time. Cost management is also effective for common change orders, which happens daily in construction. Cost can determine the type of construction, the types of fit-outs and the type of specifications.

Furthermore, the construction triangle is comprised of many compositions which eventually result in a successful project. There are a total of 14 compositions that make up the construction triangle. Each category serves a purpose in the end result. For example, architecture's purpose is to design, coordinate, ensure public safety and be creative. The purpose for engineering is to calculate, problem solve, structurally enable, and protect the public's interest. A successful project would be defined as a project that has followed all the necessary protocols to ensure an optimal deliverable.

The Impact on Our Community

By practicing all the compositions to achieve a successful project results in a positive impact on our community. In order to portray a successful project deliverable, we must analyze the thesis- working backwards. For the sake of argument, we will say that the Construction Triangular Theorem, if practiced chronologically, will have a positive impact in our community. Technological innovation, public safety and best construction practises has led to a positive impact in our community.

What Led to Technological Innovation

What led to technological innovation were a series of factors. The concept of design has come a long way. From hand drawn designs to AutoCAD, technology has improved rendering. Architects and other design professionals can precisely design elements without error. There is potential to create a two-dimensional house design to a three-dimensional design. This concept saves time, money and stress.

Engineering has also led to technological innovation. In addition to AutoCAD and various other design softwares, the innovation of structural steel and its structural components has had a major impact on technology. This practice has enhanced construction practices and improved safety. As well, calculative methods and tools have profoundly improved in the engineering world which led to technological innovations. Moreover, the practice of project management has had a technological impact. For example, the science of scheduling has become so advance that it improves the flow of construction. Up-to-date schedule softwares such as Microsoft Project are excellent software that creates schedules and points out milestones that are crucial to the project. Scheduling has improved the general flow of construction and has improved time management.

What Led to Public Safety

There are a variety of factors that led to public safety. The practice and regulation of Architecture is a starting point to public safety. Each state and provinces have building codes that Architect are to adhere to. Most notably, the purpose of these codes is to ensure that the designer and constructor are building in accordance to public safety guidelines. These guidelines stipulate proper design practices and references that will enable not only a good design, but also a right design. A right design is a sort of design implementation that aides people in building a dwelling correctly. The practice and regulation of Engineering has also led to public safety.

Structural Engineering specifically has led to public safety practices. One of the mandates that Structural Engineers are supposed to comply with is to ensure that Public Safety comes first. Their design and load calculations are crucial when it comes to safety. Their role is to ensure that while a building is being constructed, especially with structural steel framing that the installation and structure is to be durable and safe. Finally, Project Management ensures that construction projects are effectively delivered on time and within budget. As well, this scope of work is to ensure that projects are also delivered safely and according to safety regulations. Without project management, construction projects would not be structured and organized effectively.

Conclusion and Personal Thoughts

The Construction Triangle has ultimately evolved throughout history. We have proved in this thesis that Architecture is one of the initial founding elements that result in a successful project. We proved this by virtue of using various architectural and engineering scholars such as Ruth Slavid (2012), where he took us back in the field of architecture and showed us various compositions that led to the conclusion that Architecture is indeed one of the primary principles behind a successful project. Such examples of compositions were design. This is one of the most obvious compositions in Architecture. You must have a design to achieve a notable deliverable. After having a design in mind, we must coordinate with various stakeholders to move on to the next step.

Architects act as the leaders in design and most often implementation. Slavid's (2012) theories have proved that the field of architecture is complex and promotes public safety. To concur with Slavid's (2012) theories, the Ontario Association of Architects in Canada, like any other regulating body, confirms that the public's interest comes first. Marco Bussagli's (2010) book portrays a chapter on Fillipo Brunelleschi's theories on Proportional Harmony. The theory on Proportional Harmony is still used in Architecture, which ultimately proves that this practice will achieve a successful project outcome. Finally Frank Duffy's six S's laid a foundation on design principles. Furthermore, Architecture is one of the tenets of construction.

A second tenet of construction that proves a successful project is engineering. Slavid's (2012) notion that foundation is one of the vital elements of structural engineering is plausible. Calculating dynamic and static loads is crucial in this practice. Andrea Deplazes' theories on masonry bond and practice also prove that this sort of component is also one of the tenets of construction. Masonry bonding has been a common practice in building technology and building science for centuries.

And of course, the most durable and structurally sound instrument in structural engineering is I-beams and lintels. This is a good replacement for wood beams, which do exist today, but are now scarce in many areas. This is nonetheless a tenet of a successful project because this is the only plausible structural element that sustains buildings. Finally, project management serves as the "final icing to the cake." This final tenet is a mandatory component of a successful project. Without project managing a construction project, there wouldn't be a project deliverable, let alone a project. All aspects of project management reflect this sort of output. For example, acquiring a land is important before construction. This sort of acquisition had to be managed and coordinated at one point. A second example is transitioning a design element to hard construction such as the outer perimeter and the demising walls of a building. If this element was not coordinated in any light, there would be no output and therefore no completed project. In addition, it is fair to group the broad fields of architecture, engineer and project management in a triangular format and call it a construction triangle and by practicing each field professionally, we can not only achieve a successful project today, but also in the next generations to come.

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