Application of the Design Structure Matrix (DSM) to the Real Estate Development Process using Modular Construction Methods

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Submitted to the Program in Real Estate Development in Conjunction with the Center for Real Estate in Partial Fulfillment of the Requirements for the Degree of Master of Science in Real Estate Development

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ABSTRACT

Real estate development (RED) has traditionally been a very dynamic business, where real estate developers strive to turn an idea into a real asset, by delivering a quality project on time and on budget. In recent years, Modular Construction Methods (MCM) has arisen as an innovative solution to commercial RED projects that require higher levels of the three aforementioned factors, with a special emphasis placed on time.

The purpose of our thesis is to explain MCM and its impact on RED by analyzing the interdependent relationships between the different tasks performed during the course of a development. We have accomplished this by using the Design Structure Matrix (DSM), a systems engineering tool, to map out the dependencies between development tasks in a graphical manner.

To develop our DSM model for an RED process that uses MCM we conducted interviews with the senior management at RJ Finlay, a New Hampshire based full service real estate firm and Keiser Industries, a modular manufacturing company that operates in Maine and is owned by RJ Finlay.
To fully understand the real application of the MCM process to RED, we met with the general contractor, lead architect and project management team for 30 Haven, a commercial RED that uses MCM. 30 Haven is located in Reading, Massachusetts and has been co-developed through an integrated project delivery (IPD) process by RJ Finlay and Oaktree development, using an in-house general contractor and Keiser Industries as its modular manufacturer. Our interviews occurred weeks before the project was completed in the summer of 2012. This allowed us to interview the involved parties about the whole process from inception to construction completion. This helped us further understand the actual problems a RED process using MCM can face throughout the preconstruction and construction processes.

We then developed a DSM that showcases the different stages that a RED process using MCM have to go through and the planned and unplanned iterative processes for each stage. Planned iterations are feedback loops between tasks that are meant to rework tasks that forcibly need it, while unplanned iterations reflect feedback loops that occur because of unexpected events.

Our thesis has focused on proposing proactive solutions to the unexpected events (referred to as "failure modes") a RED process using MCM can face, by either eliminating them or minimizing their likelihood and impact. The DSM helped facilitate the development of both a normative model and an optimal one, where our solutions for the unplanned iterations were applied. We complemented our findings with a hypothetical financial model that uses the normative and optimal DSM models to show the difference between both in terms of the returns, time and cost for a generic multifamily RED that uses MCM.

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Chapter 1: Thesis Purpose, Goals and Methodology

Chapter Introduction:

This chapter introduces the purpose of our thesis, which is to document how modular construction methods are applied in the commercial real estate development process and to better understand the benefits of using modular design and construction methods. We focus on uncovering the limitations and potential risks in the development process for modular construction. We do so by using a systems engineering approach known as the Design Structure Matrix (DSM) method to map out the information flows and task-related relationships between the different parties involved (the modular manufacturer, the designers and engineers, the general contractor and the developer). This research partially builds upon the RED stages identified by two earlier Massachusetts Institute of Technology Master's in Real Estate Development (MSRED) theses by Cameron and Di Carlo (2007) and by Bulloch and Sullivan (2009), and completes (and redefines) the missing stages to conform the stages to an RED process that uses MCM.

Thesis Purpose:

The main purpose of our thesis is to describe and analyze, in detail, a commercial RED process that uses MCM. With a high degree of scrutiny we expect to uncover in a holistic way the complexity that is characteristic of both processes and, in doing so, to find ways to emphasize potential solutions for the expected complications in the process.

We have accomplished this through the use of the DSM, a systems engineering tool which promotes a deeper analysis of the intricacies that are present in every RED process. By going through the analytic rigor required in mapping out the process in the DSM, it has become possible to ask the right questions and receive guidance towards addressing the proper solutions. **We are specifically targeting the identification of unplanned iterations in the RED process using MCM and are looking to address them by promoting solutions that either eliminate or minimize their likelihood and impact.** We do this in a twofold manner: firstly, by achieving optimization directly via the DSM (through the resequencing, elimination and addition of different tasks) and secondly, by producing costs and time savings through a hypothetical financial analysis that models a generic commercial RED process that uses MCM.

Through the research efforts present in this thesis, we expect to spur further research by others in the application of this systems analysis and project management method to continue to ask meaningful questions that potentially point towards the right answers. We attempt to lay the groundwork for future DSM applications in the RED process and to further advance the overall academic and practical understanding of the RED process. More detail on future applications of the DSM to the RED process that uses MCM is available in Chapter 10.

Thesis Goals:

We focus on achieving three distinct goals in order to validate the purpose of our thesis:

1) **Understanding the RED and MCM process:** To understand the communication flows and task dependencies between the different parties involved in the RED and MCM processes and to identify failure modes that describe where and why these processes fail. Naturally, we will also look to define what a "failure mode" means in this particular context. Chapters 7 and 8 focus on failure mode identification and solutions.

2) **Proposing proactive failure mode solutions (qualitatively and quantitatively)**: To propose proactive and applicable solutions to all expected and potential failures in the RED process that use MCM by comparing a "normative" application of the DSM with an "optimal" one. While the "normative" application of the DSM models an ideal RED using MCM scenario, it still accounts for unplanned iterations (i.e., unexpected events). An "optimal" DSM model represents solutions to those unplanned iterations, either through their elimination or by minimizing their likelihood and impact Our solutions will be based on real-life development process solutions as derived from interviews we conducted with a variety of real estate professionals, as well as our own academic conjecture. Our research will also be corroborated by a hypothetical financial analysis which will model the "normative" DSM model's returns in terms of the additional time and money taken up by the "normative" DSM's unplanned iterations, which we will use to compare with the "optimal" DSM model's own returns. The difference in returns, time and costs between both will determine the savings that can be attained through the elimination or reduction of unplanned iterations. For more information on our financial analysis, see Chapter 9.

3) **Case Study example:** To showcase a case-study example of a commercial RED project that uses MCM and to explain how the failures and potential failures identified in this particular commercial RED project and both processes can be and were addressed in a real-world setting by the different parties involved.

Methodology

Secondary Data Collection

Our MCM data was derived primarily through Cameron, Jr. (2007) and Di Carlo's (2007) MSRED thesis titled "Piecing Together Modular: Understanding the Benefits and Limitations of Modular Construction Methods for Multifamily Development". Chapter 2 explains in further detail the specific data we derived from the thesis and how we relied on it to further our investigative process regarding modular construction methods. We also embarked on understanding the difference between MCM and conventional Stick-Built Construction when applied to commercial RED projects. We relied on Jordan M. Fray's East Tennessee State University thesis titled "A Comparative Study of Modular and Stick-Built Construction of Multi-Family Properties" to understand the differences between both methods based on the factors the author deemed most important to compare: design constraints, speed, cost, quality, sustainability, material storage, security, permits & inspections and financing (Fray, 2010).

Our DSM data were derived from Bulloch (2009) and Sullivan's (2009) thesis "Application of the Design Structure Matrix (DSM) to the Real Estate Development Process", as well as activity-based DSM process examples and methods we consulted in Prof. Steven Eppinger's recently published book "Design Structure Matrix Methods and Applications" (Eppinger & Browning, 2012).

Primary Data Collection

To collect, document and validate the information regarding the RED and MCM processes we went directly to the source for each. For the former, we interviewed the senior management that worked for a commercial real estate developer that had experience going through the process using MCM, and for the latter, we interviewed the respective management of a modular construction manufacturing plant that serviced real estate developers looking to develop commercial real estate projects using MCM. To fully understand the communication flows between and interdependence in tasks as completed by the developer, manufacturer, general contractor, architects and designers we targeted a fully integrated real estate developer, so as to avoid any conflicts of interest or misaligned incentives (assuming that a fully integrated real estate developer has all of its parties aligned and intent on achieving the same goal: completing a RED project on budget and on time) to ensure that the information we would be receiving would be as factual, transparent and all-encompassing as possible. For further detail on primary data collection, refer to Chapter 4.

Thesis Premise

Our premise concerning the RED process that uses MCM is that it is simply a more cost-effective, and timely process which can service a particular niche market that focuses primarily on single family homes and multifamily developments. We are plainly assuming that MCM methods provide more quality control and shorter project time frames yet are still exposed to considerable limitations concerning size and design.

We look to describe the RED process that uses MCM in detail and will highlight our findings and the differences between MCM and traditional site-built methods through our primary and secondary information sources. We provide a general comparison of MCM and traditional site-built methods in Chapter 3.

Our premise rests on the assumption that when we use the DSM to analyze a commercial RED process that uses MCM, we will derive alternative methods to manage complexity in the RED process, specifically focusing on:

1) **Identification of failure modes**: Failure modes and effects analysis (FMEA) (Failure Mode and Effects Analysis (FMEA): A Guide for Continuous Improvement for the Semiconductor Equipment Industry, 1992) are more commonly used in product-based manufacturing processes, but the principle relating to the identification of failure in a process, the analysis of how it occurs and its effects is key when attempting to determine an alternative approach towards addressing activity-based RED and MCM problems.

2) **Communication flows / Interdependent tasks:** To explicate the full failure mode in both the RED and MCM processes, we look to dissect the different communication flows and adjoined interdependent tasks between parties to understand how either sequential or iterative flows should be addressed: whether through re-sequencing, elimination or the creation of new activities. We then look to make use of these solutions to address the unplanned iterations that come naturally to any RED process that uses MCM, with the expectation that, through our solutions, real estate developers can plan and prepare for unexpected situations.

Chapter 2: Introduction to Modular Construction

Chapter Introduction:

In our attempt to further understand modular construction, we focused solely on identifying sources of information that would provide data on the type of modular manufacturing firm and process that could be deemed comparable to Keiser Homes, a modular manufacturer based in Oxford, Maine, owned by RJ Finlay, a New Hampshire development firm who agreed to work with us for the purposes of this thesis. In essence, we wanted to complement the information we would be documenting from our interviews with the firm, our primary source, with any available research that described the modular process as carried out by similar New England based firms; firms that ideally produced modules which use lumber as its raw material to then assemble the "boxes" via a wood frame. A previous MIT thesis, written by Cameron, Jr. (2007) and Di Carlo (2007) focused on modular manufacturing that represented these aforementioned characteristics. We completed our understanding of the modular process by going through the process with the Operations Manager for Keiser Home's modular manufacturing plant and complemented our findings with the process described by Cameron and Di Carlo in their 2007 thesis.

General Modular Manufacturing Process

In Cameron and Di Carlo's 2007 MSRED thesis, the authors identified the following sub-activities as part of the overall modular manufacturing process (Cameron, Jr. & Di Carlo, 2007):

1) The Factory

Concerning the different activities required for the assembly of the modular "boxes" in the factory. The thesis identified elements relating to design, plant management, lumber/material checks, framing, component installation, priming & prepping, storage and quality control in the factory.

2) Transportation

Concerning the rules and regulations between U.S. states and the effect they have on transporting modules to the site where they will be erected. The authors mention how requirements for modular transportation pose limits on the maximum height and overall size the modules can have, making them less flexible to certain types of commercial real estate development designs.

3) The Set

Concerning the setting of the modules on the site via crane and the subsequent "marriage" of the MEP (mechanical, electrical, and plumbing) connections that occur between the systems installed on the modules in the factory and those that are being put together on site.

4) Inspection and Quality Control

Highlighting the focus on the thorough inspection and quality control that modules go through in the factory and the ensuing quality control when they are set and become a single building.

5) Site Work – before, during and after manufacturing modules

This stage accentuates the importance of the pre-site work that occurs in parallel with the manufacturing of the modules and the post-site work that focuses on coordinating the delivery of the modules, the marriage of the systems, and the eventual delivery of the final product.

During our interview process with Keiser Industries, we documented the information coming from the activities that occur in a modular manufacturing plant, and paid special attention to the limitations placed on modules that are transported, as well as the intricacies relating to the setting of the modules on the site and the subsequent inspection and quality control for the individual modules and completed structure.

Advantages and Disadvantages of Modular Construction

The following summarizes the advantages and disadvantages of the modular construction process that we identified in the thesis. *Chapter 3 will provide a deeper analysis of the advantages and disadvantages in MCM, when compared to Site Built methods.*

Advantages:

- Time savings
- Labor cost savings
- Minimal Change orders/Cost overruns
- Quality control in the factory and On-Site
- Less waste

Disadvantages:

- Limitations in size
- Limitations in design flexibility
- Limitations in MCM process

- Transportation issues
- Marketing issues

Chapter 3: Site Built and Modular Construction Methods Comparison

Chapter Introduction:

Modular construction has traditionally been an option for single family developments, with the concept of "manufactured housing" being central to the definition of the type of construction methods employed for this market segment. Manufactured housing is defined as a "A structure, manufactured in one or more sections, which is built on a permanent metal chassis and designed to be used as a dwelling with or without a permanent foundation when connected to utilities and includes plumbing, heating and electrical systems, manufactured in accordance with federal standards under the National Manufactured Housing Construction and Safety Standards Act of 1974 (42 U.S.C.A. §§ 5401-5426). (www.modularhousing.com) "Modular construction has also steadily become more prevalent in the commercial RED market in recent years, but has yet to become as commonplace as site built construction. In 2010, permanent modular construction (general statistics on modular construction includes both moveable and permanent structures) accounted for a $2 billion market share, an approximate one per cent of the U.S.'s total building market. The total modular construction market in the U.S. was $5 billion in 2010, with 42% of that total attributed to permanent modular construction. 5% of the total was invested in Retail/Hospitality, 20% in Multi-Family/Student Housing and 26% in Office properties – the rest was attributed to Education and "Other" building projects, according to the Modular Building Institute's 2011 annual report (Permanent Modular Construction 2011 Annual Report). Hybrid construction methods that combine modular construction with site built have been catching on as more and more commercial mixed-use projects profit from building retail spaces, underground parking garages, and the building's foundation on site; all in parallel to manufacturing the modules that will later be put together on the site to complete the project's multiple floors of residential space. Panelized, pre-fabricated and pre-cut elements have also been adopted as more efficient "modular-type" construction methods, helping projects achieve completion on time and on budget. However, in order to fully understand modular construction's relevance and place in today's construction market, it is necessary to compare it to alternative commercial RED construction methods, in particular, site built methods, which deviate the most from what MCM has to offer. This chapter will highlight the main differences between site-built and MCM and will also reference the causes of construction delays, relying on Odeh and Baittaineh's list of principal factors that affect construction and cause delays, per their publication "Causes of construction delay: traditional contracts" (Odeh & Battaineh, 2002) in the International Journal of Project Management.

Researching Site Built vs. MCM:

While empirical studies on MCM are scant and sparse, there are numerous studies that have focused on researching "modularity" and its positive effects on manufacturing processes. In the book "Design Rules, Vol. 1: The Power of Modularity", authors Carliss Y. Baldwin and Kim B. Clark argue that modularity, when employed in a product's design, can produce great benefits, and can only be exploited through *design rules*, as was done when the computer industry became "modularized" and computer's started adopting design rules (Baldwin & Clark, 2000). The importance of "design rules" and a module's design cannot be underestimated when thinking of MCM: it's not just how quickly one can construct a module; it's how effectively the module is designed and how efficiently that design is implemented.

After interviewing the General Contractor (GC) for 30 Haven, RJ Finlay's modular construction project, and, the Operations Manager (OM) for Keiser Industries, who supplied the project with its modules, we found a common thread in their narratives. Both of them referred to the learning curve (LC) which subcontractors face when having to "marry" the MEP systems installed in the module manufacturing factory during the setting process that takes place on the site. To our surprise, the construction contracting market does not always supply experienced MEP systems workers for the job. Naturally, developers and GCs prefer to work with experienced subcontractors to eliminate this bottleneck, but this is not always possible.

30 Haven's lead architect, who leads an in-house structural engineering team that used Building Information Modeling (BIM) methods to design the modular components of the project, touted the BIM software they were using to design the project, in an attempt to have it serve as a set of "design rules" the project could follow. Certain modules in the project have certain connections and graphical three dimensional accesses that pinpoint where the different MEP systems connect with the adjoining modules. This *design rule* advantage could potentially reduce the difficulties that result in understanding 2D CAD drawings that don't explain how the systems are connected when the modules are set together. Proper "design rules" in this context would provide clarity, and easy-to-follow tasks that could help the LC become less daunting, and as such, provide additional benefit to MCM's core value: saving time.

The following can be considered as part of the potential "design rules" repertoire that would make MCM processes less prone to delays and bottlenecks:

1) BIM design

As identified by Azhar, Hein and Sketo in their article "Building Information Modeling (BIM): Benefits, Risks and Challenges", BIM provides benefits in speeding up information-sharing and value-add processes, better design, controlling costs, automating assembly, increasing production quality, providing superior customer service and more efficient use of data (Azhar, Hein, & Sketo, 2008). There is a direct benefit to MCM given that everything that is accomplished by BIM can be uniformly applied to any process that focuses on translating design into construction. Adopting this system, though, requires an up-front cost in terms of the software's cost and personnel training.

2) Alternative Electronic Documentation of Processes

The use of electronic documentation to note and address bottlenecks and potential delays in manufacturing processes can promote real-time information sharing between parties, which can result in addressing problems quickly enough to provide measurable benefits. The use of tablet computers or specialized computer systems in the factory can make this possible.

A Case for MCM:

In a very general sense, it would be expected for any uninformed person to very easily deduce that the primary advantage in MCM is the reduction in time it offers developers vs. traditional site built construction. The reason for MCM's reduction in time can be attributed to the fact that modules are manufactured in a fast, controlled and safe environment with contractual, material, labor, financing, payment, and city/state approvals arranged up front. In typical site built construction projects, there are multiple issues the developer has to face, problems that collectively produce the multiple delays that are normally present in most construction projects. The following table denotes a summary of the factors afflicting site build constructions identified by Odeh and Baittaineh in their article "Causes of construction delay: traditional contracts" (Odeh & Battaineh, 2002):

Factors	Potential Problems
Client - related	- Finance/Payments of completed work - Owner interference - Slow decision making - Unrealistic contract duration imposed by owners
Contractor - related	- Site management - Improper planning - Inadequate contractor experience - Mistakes during construction - Improper construction methods - Delays caused by subcontractors
Consultant - related	- Contract management - Preparation and approval of drawings - Quality assurance/control - Long waiting time for approval of tests & inspections
Material - related	- Quality of materials - Material shortage
Labor & Equipment - related	- Labor supply - Labor productivity - Equipment availability - Equipment failure
Contract - related	- Change orders - Mistakes and discrepancies in contract documents
Contractual relationships - related	- Major disputes and negotiations during construction - Innapropriate organizational structure linking all parties involved in the project - Lack of communication between parties
External factor - related	- Weather conditions - Changes in regulations - Problems with neighbors - Site conditions

(Odeh & Battaineh, 2002)

Table 1 – Causes of construction delays

While MCM are exposed to the factors listed out in the table above, there are specific ways in which MCM addresses the difficulties that lie therein:

Client Related Factors:

Slow decision making and unrealistic forecasts for project duration can be thwarted when the developer and banks both have a clear sense of how long the project will last. This is something fully accomplishable with MCM, a process in which the scheduling and deadlines will not vary much throughout the project's total duration. On-site construction will be coordinated with the manufacturing of the modules, which will then be set on site, all in an efficient manner. The opportunities for delays are minimal when the process is done correctly. Ideally, a streamlined process will make sure to count on manufacturers, GCs, and subcontractors who have been through the process before. However, even when this is not the case, as long as the developer and GC know the RED using MCM process, they will be able to help subcontractors and other parties go through an intensive learning curve process so as not to completely deviate from the original schedule and deadlines.

Contractor Related Factors:

While site built methods progressively "ramp up" the number of subcontractors working on the site as the project progresses, MCM requires every subcontractor to start working from day one. This poses a unique challenge: subcontractors are required to "marry" the MEP, data, fire protection and other specialty systems all at once, sometimes without any previous experience. Many times, subcontractors shy away from doing so, fearing mistakes, but once the connections are explained by the manufacturer's set crew (composed of laborers, engineers and designers) to subcontractors - they speed up their work considerably.

Mistakes during construction are minimized considerably when using MCM, due to the constant attention given to individual modules, first in the factory when they are manufactured, and then again on site once they are set. There are also multiple revisions to the modules as the subcontractors work on connecting the systems between them. In site built methods, it is common for a mistake to go unnoticed while work is being performed elsewhere in the building, only coming to light once the final overall inspection is performed, or when the building is occupied. While not every MCM project will have experienced subcontractors, they are still "taught" what to do, and as such, are led through the process by the developer and GC, to avoid mistakes and ensure quality construction work. In site built projects, subcontractors can have low quality and inexperienced labor working on the site, putting the developer more at risk for potential rework, whereas this risk is prevented in MCM through the elimination of the independent relationship between the subcontractor and the developer's modular manufacturing and engineering arms. In MCM methods, the subcontractor is required to work with the teams that manufactured and designed the modules. Subcontractors can work with the manufacturers early on when the modules are being fabricated in the plant, as the systems are first installed per module. This way, the subcontractors are acquainted with the modules and how they function. Labor in MCM perform specialized tasks and end up being more than a "hired hand", while in site built methods, the labor can more easily detach themselves from delivering the best quality and just accomplish the bare minimum.

Consultant Related Factors:

Approvals and inspections are streamlined through the MCM process early on. Third party inspectors are forcibly hired by the developer to visit the module manufacturing plant and inspect the modules to make sure they adhere to state and local agreed-on quality standards. Final designs and drawings are also approved before the modules are shipped out to the site, which ensures that everything that is to be set on site has been pre-approved. A big distinction between site built and MCM is the distinctive role (which site built methods lack) that third party inspectors have in MCM: often, inspections are done in site built projects once the buildings are completed, with inspectors having to revise a complete building to their discretion. Anecdotal evidence regards inspections as being superficial, time-pressured and as such, permissive and tolerant of unacceptable design and building construction errors (Fray, 2010). Reports show how the market sometimes demand certain designs for single-family, multifamily and commercial products that cannot be accomplished with MCM, given that MCM has to have its modules and design adhere to building codes in the factory, before they are inspected, while site built projects can take the risk (knowingly or unknowingly) of choosing unapproved designs and having these ultimately approved by the building inspectors.

Material Factors:

Materials for MCM projects are sourced for both the onsite infrastructure (and non-modular commercial space) and the modular manufacturing plant at the beginning of the project's timeline, in parallel. The material's quality is directly correlated to who the modular manufacturer is, and their track record. Inasmuch as the modular manufacturer has the correct systems in place to ensure high quality for the materials used, the developer will hold an advantage. Material shortages are not an issue as long as the modular manufacturer has the correct systems in place for proper material procurement and assures the updating of material requirements through proper optimal manufacturing methods and just-in-time (JIT) methods as finalized modules start to be shipped to the site.

MCM has various material quality assurances that site built methods might not be able to guarantee. Primary amongst these assurances is the guaranteed benefit that comes from building the modules in the manufacturing plant's dry environment, which limits the module's exposure to harmful weather and vandalism once they're shipped to the site. Site built methods expose the building to weather, and when materials are exposed to rain and wet environments, they promote mold and other ills associated with material exposure to humidity.

Labor and equipment Factors:

Labor in MCM takes a different form than in site built projects, mainly because the labor that is employed in MCM is split into two camps: manufacturing-based labor and construction labor. Manufacturing-based labor has the advantage of becoming very predictable and reliable given the consistent nature that comes from manufacturing. Keiser Homes is also able to offer a more competitive module product to RJ Finlay's projects based in states where labor rates are high, such as Massachusetts, mainly because the labor rates are, in general, lower in Maine than in other markets within the northeast US region.

Construction labor is composed of the workforce that works on erecting and putting together the building onsite. In the case of site built methods, construction labor would make up all the labor involved in the project. In an RED using MCM, construction labor is employed when constructing the foundation, infrastructure and non-modular commercial space the project in question requires. The construction labor that is required later, mainly supplied by the different specialty subcontractors the GC hires to help connect the different modules during the setting stage, differs from the subcontracting in site built methods in that MCM deals with every subcontractor and full crews in one fell swoop, while site built gradually starts adding subcontractors and the number of workers for each crew as the project progresses.

While there are always issues with worker productivity in any development, MCM's manufacturing factor and its effectiveness influences the non-manufacturing activities that take place in the different stages of the development. An "optimal" manufacturing and time-conscious strategy is first executed when constructing the infrastructure onsite, in parallel with the modular manufacturing in the factory. The same optimal manufacturing mindset is then continued when the factory's site crews work alongside subcontractors in an efficient, measured process to set the modules and connect them on site. Site built methods, while also working under time-based pressure to keep to a construction schedule, still count on additional time and flexibility needed to determine the final design of the building which MCM does not have, primarily because all design decisions have to be finalized and effectuated before the project begins.

Contract Factors:

The occurrence of change orders is decreased with MCM because RED projects using MCM require design decisions to be made up front, thus causing change orders coming down the line to become very costly decisions. While change orders are still allowed in MCM, the manufacturer will have to compulsorily enforce an expense towards (i) altering the modules that were already manufactured to conform to the new change, (ii) incur additional costs relating to the change itself and (iii) cause a delay to the whole manufacturing process in order to enforce the changes required. Even though site built methods offer more flexibility (in time and cost management) when it comes to implementing change orders, MCM can still implement changes with minimal cost, as long as the change minimally affects the rest of the modules, and can be applied to select modules (in effect, avoiding having to rework already completed modules). While change orders cause additional costs to the RED process, they also cause substantial time delays, which, are by themselves, more harmful to the development process. More data on how additional costs and delays affect the RED process's bottom line can be seen in Chapter 9.

Contractual Relationship Factors:

In any project, whether it is site built or an MCM project, the development will fare better if there's an alignment of incentives and a clear communication flow between all the parties that are involved. In MCM projects, the developer is better able to streamline the development process by integrating the manufacturer with the building design to properly translate the architect's vision into engineering-based shop drawings followed by the integration of the efforts between the manufacturer's site crew and the respective MEP subcontractors to "marry" the systems between the modules in the setting stage.

MCM projects are naturally inclined to have the different parties involved support each other, and as such overall incentives become aligned, the main one being: to complete the project on time and on budget. Site built projects sometimes fall into the "hired hand" trap, where the GC, subcontractors and independent architects, engineers and designers, only act as "hired hands" and provide their respective services, without concerning themselves with the project's potential delays that could result from a lack of integration and co-planning.

External Factors:

External shocks (environmental, political, economic, financial, organizational and other types of shocks) present unpredictable situations that can affect both a site built project and an MCM project. However, MCM projects can more effectively deal with shocks due to their shorter duration, dry-environment manufacturing which protects the modules from bad weather and simpler, more practical designs.

Chapter 4: Field Work Research

Chapter Introduction:

We relied on a managing director for RJ Finlay & Co., a full service real estate, construction, and building materials firm, to assist us in arranging interviews with the CEO, the Operations Manager, and Sales Manager at Keiser Industries, RJ Finlay's Maine-based modular manufacturing plant. We were also able to arrange interviews with the GC/Construction Manager, Head Architect and the rest of the Construction Team for RJ Finlay's latest multifamily RED modular-based project, 30 Haven, in Reading, Massachusetts. The aforementioned senior managers and executives have all worked with RJ Finlay prior to this project and have experience working together under an integrated project delivery (IPD) environment, where the design-build construction method was employed to undergo a commercial RED project. This chapter profiles RJ Finlay, Keiser Industries, its OM, GC, and Lead Architect for 30 Haven, a mixed use, mid-rise commercial RED that utilized MCM, with modules supplied by Keiser Industries and development services carried out by RJ Finlay.

Company Profile: RJ Finlay

RJ Finlay is an integrated real estate developer and services firm that throughout the years has partnered with and invested in both companies that produce building materials, construction (both modular and non-modular), and firms that focus on real estate investment and asset management. The company has also collectively acquired and developed more than thirty commercial, multi-family and residential projects in New Hampshire, Massachusetts, and Florida. The firm targets Class B buildings (Class B buildings are meant to target non-premier users, who pay average rents in smaller cities or more suburban locations, with building finishes that are non-luxurious and exteriors that are satisfactory to the area) in secondary markets and is active in promoting commercial and single-family modular based development (RJ Finlay & Co.).

Project Profile: 30 Haven

30 Haven is a mixed-use commercial RED project that is being developed via a joint venture between RJ Finlay and Oaktree Development. The project uses MCM and includes underground parking, a ground floor that covers 22,000 square feet of retail/restaurant space and a total of fifty-three residential units. This project was developed through an Integrated Project Delivery (IPD) process, with the co-developers, GC, lead architects/engineers and module manufacturer all working in unison. Oaktree development and its construction arm have worked alongside RJ Finlay and its modular manufacturer, Keiser Industries, to provide both the onsite and offsite work for the project (30 Haven). The IPD process employed by 30 Haven's development team has made the project flow smoothly and has also helped establish an efficient

design-build delivery method for the design and construction of the project. Having all parties agree with the project's design, program, and schedule early on makes the construction process more linear, with less time wasted between parties looking to agree with each other. Having all incentives aligned between parties and working towards the same goal, all coupled in with the MCM has made the project flow smoothly. Figure 1 (RJ Finlay & Co.) below shows a design of 30 Haven, with a view of the retail ground floor and three levels of residential units.

Figure 1 – 30 Haven

The following summarizes the key subjects discussed with the GC and lead architect that concern a general discussion of their experience in the management and execution of RED projects that utilize MCM, drawing upon various situations they recently experienced in the 30 Haven multifamily commercial RED. We also interviewed the OM for Keiser Industries, the modular manufacturer for the project, and we discussed the process a modular manufacturer follows in the factory to effectively produce modules and the process followed when manufacturing modules for commercial RED projects.

Interview with General Contractor (GC)

General Contracting for an RED project using MCM

The GC for 30 Haven guided us through the both the development and general contracting processes employed by developers and GC's looking to execute projects using MCM. The GC is a professional architect who currently works for Urban Spaces, LLC, a local developer and general contracting firm based in Cambridge, MA, who was hired by and has previous experience working for RJ Finlay.

RED Process using MCM

The bulk of the data we collected from this interview was then used to map out the RED process DSM (Figure 18). The specific activities derived from these interviews and further details on the steps in the process are referred to in Glossary 1. The main subjects discussed during the interview were the financial analysis, acquisition, entitlement phase, design phase, building permits, construction, site prep, transportation, module setting, and building completion stages of the process. The following provides details about each topic discussed during the interview:

Financial Analysis

The main focus for the developer when it comes to determining whether an RED project will be modular or site built is to understand where the potential savings are, and identifying whether MCM's main advantage in saving time is more beneficial than flexibility in design, a main advantage in site built methods. If a project, for example, has to be delivered by a certain time, as happens with student housing - then, using MCM would guarantee a shortened completion time, and with that, earlier income streams. If a project is aiming to derive premium value from a grandiose design or command a larger number of leases/sales that can come from a high rise development, then an MCM process will fall short.

Basic preliminary financial underwriting can help the developer realize whether the project will profit from modularity. More formal market research will be performed afterwards to validate the development idea. Financial analysis and underwriting will increasingly become an iterative process as the development progresses and the developer looks to reinforce and validate the idea that modularity is the best solution for the project in question.

Acquisition

Acquiring the property and considering multiple land control options becomes a necessity once the project has been approved. The developer's organizational strategy and his approach to development then takes one of two routes: either (i) *a use looking for a site* or (ii) a *site looking for a use?* (Miles, Eppli, & Kummerow, 1998).

Entitlement Phase

Entitlements are essentialto any development, and are needed to improve initial conceptual and schematic designs. Just as with any development, an RED process using MCM will require variances and special permits if needed.

Design Phase:

The ideal MCM process requires for the developer, GC, lead architect, lead engineers, and modular manufacturer to be on board with the design process. Primary amongst those that have to be involved are the developer's architect and engineers with the modular manufacturer, who will have to eventually convert the project design into shop drawings needed to build the individual modules. During the interviews, the following three things were identified as strategically important activities required to make sure the project would not encounter unnecessary delays:

1) The modular manufacturer must be involved with the design process from the very beginning to ensure a productive relationship between the parties from the start.
2) The project's architect must be on board with the process, approving any preliminary and subsequent design change alongside the other parties.
3) Proper follow-through and communication between the manufacturer and the developer's design team is required to maintain a truly integrated effort.

Building Permits

The municipal building department and the division of public safety for the state where the project will be built are the entities who will be providing permits for the RED project. Since MCM has all the "pieces" of the building manufactured and then put together on the site, it is more difficult for inspections to occur onsite. As such, by law, the modular manufacturer is required to hire a third party inspector that will inspect the modules the manufacturing will be producing at the manufacturing plant. The third party reviewer will not only inspect the modules themselves, but also the process followed to manufacture them.

Initial Construction – Site Prep

The excavation, foundation, demolition (all for which a permit is required), erecting the steel and having, if required, underground parking, non-modular commercial space and other structures that will lie below the modules, all must be completed before the modules are set on site. To make this process more efficient, onsite construction is done in parallel with the manufacturing of the modules. An optimal situation would have the site work completely ready immediately before the modules are set to arrive on site. Figure 2 and 3 below show the excavation/preparation for the foundation and underground parking and the steel structure erection for the retail ground floor at 30 Haven ((Lead Architect for 30 Haven, 2012).

Figure 2 - Excavation and preparation for the foundation and underground parking

Figure 3 - Erecting the steel for the retail ground floor

Module Manufacturing

According to the interviewee, most manufacturers can produce about seven to ten boxes per week, and take about three months to build an average low rise (three to four floors), forty to fifty residential unit development. Before being set on site, finished boxes are stored at the manufacturing plant, where they are accessible in case any damage occurs or a change needs to be made. Once the modules leave the factory, they are at greater risk, mostly because as separate units they are worthless, and fixing them becomes much costlier once they are out of reach. In essence, there is no value to any of the modules until they are part of a complete building. Figures 4, 5, and 6 show the different activities that take place in the modular manufacturing facility before the modules are primed and prepped for transportation (Homes, 2012).

Figure 4 - Mill work modular pieces

Figure 5 - Modules are framed and set on the tracks

Figure 6 - Modules insulated and connections are made

Transportation

As site preparation is completed, the modular manufacturer can begin shipping the modules. By that time, a substantial number of modules have been produced and, many times, the manufacturer has been waiting for the site to be ready to start shipping. In most cases, the manufacturer does not reach the point where it must wait for the site to be ready after having finished all the modules; normally the manufacturer can start shipping modules after having finished most of them, but not necessarily all the ones that are required. Figure 7 and 8 show the modules in the condition they need to be in before they are transported on site (Homes, 2012).

Figure 7 - Primed and prepped module for transportation

Figure 8 - Module ready to be set on trailer

Setting

Cranes are placed on the site and a special place is designated as the “Staging Area”. Modules are brought in on trailers, unloaded from the trucks, and then set.

General Contracting in RED Projects using MCM

General contracting for RED projects using MCM poses unusual challenges for GC's. Obstacles predominantly arise when having to coordinate the different subcontractors who will be working with the module manufacturer's site crew to set the modules together and connect the MEP systems between them. During the interview, we identified three main areas which a GC has to address:

1) **Coordination of trades**: It is typical to work with subcontractors who have not dealt with modular construction before, whether because of a subcontractor's labor turnover (with those workers who might have experience working in modular gone before the GC is able to make use of them) or because of limited experience in the number and type of modular projects the subcontractors have worked on. Subcontractors will be hired to provide full crews to service the plumbing, HVAC, electrical, drywall and carpentry for the project. There is, in effect, a considerable learning curve (LC), where a lot of the time gets lost. Many times, the subcontractors, depending on how complex their specialty is, can be involved with the manufacturing of the modules from the very beginning, in order to either help design the module or to fully understand where the work and system connections will be.
Coordinating the different trades poses a multifaceted problem for the GC during the construction phase of the project. The different subcontractors will all be working onsite at the same time, and it will be the GC's responsibility to help alleviate the LC process for the different subcontractors and to have their work properly revised to uphold the required quality standards.

2) **Completing the product:** By this point, the LC has passed and the product has now been assembled. Concluding activities including placing the roof on the structure, installing the exterior siding, connecting all the remaining piping, electrical connections and wires down to the main panels, completing the exterior site work, and finishing up the hallway spaces. This is followed by a punch list with all the "to-do" final items to take care of before wrapping up the construction phase. But like with any construction, there are always systemic problems that can arise. Building codes and regulations, design flaws, improper systems integration and poor construction could get in the way of the building's completion. Sometimes even design misinterpretation by either the modular manufacturer or the GC and subcontractors can cause considerable rework to be done onsite, incurring major time delays and additional costs for the project.

3) Quality Control and Inspection: During the final stage of the construction process, once everything is ready, the building inspector comes and completes the necessary inspections as he or she would with any regular building. Any issues with substandard quality will be pointed out and quickly resolved by the GC, helping identify the responsible party and holding them accountable for the fix.

Figure 9, 10, 11, 12, 13 and 14 show the process the modules go through once they arrive on the site (Lead Architect for 30 Haven, 2012).

Figure 9 - A crane onsite stacks the modules together

Figure 10 - A crane on site stacks the modules together (2)

Figure 11 - Modules are set together and MEP systems are connected

Figure 12 - All modules and systems are connected

Figure 13 – Inside finishes and residual work on MEP connections

Figure 14 – Exterior finishes

Interview with the Lead Architect (LA)

The Lead Architect (LA) for 30 Haven was hired by Oaktree Development, the developer who partnered with RJ Finlay to develop the project. The LA works for AbodeZ, a Cambridge, MA based developer who has an in-house engineering and architectural team with experience in the design and development of modular-based multifamily projects.

Our conversation with the LA was centered on the design of modular commercial RED projects and its role during the different stages of construction and manufacturing that occur until the building is completed.

<u>Initial Design and Integration with Modular Manufacturer</u>

Before starting to build on site, the required designs to start manufacturing modules are the building footprint and the unit plans. However, the MEP and overall systems design happened in concert with Keiser Industries. For 30 Haven, there was a lot of coordination upfront with the manufacturing of the modules. The upfront planning was essential in lowering the amount of construction administration for the project overall. AbodeZ was able to team up with Keiser in order to have as much systems work done on the modules as possible. The ductwork, for example, was done in the manufacturing factory, so as to avoid having to install it onsite. Abiding by rules and regulations like fire ratings, thinking about where the fixtures go and how they will subsequently connect, how they're placed and how the overall systems are going to be run once the modules are set are all key elements that have to be incorporated in the module's design before manufacturing begins. According to the LA, there is no better way to accomplish this than by having the developer and architect work closely with the manufacturer and with those that require the installation of specialty systems (like some subcontractors and fire safety professionals).

A particularly strong focus was also given to the building's design so as to avoiding a "modular" appearance.

<u>Design Roles</u>

The Primary Coordinator – The Architect:

The architect acts as the official gatekeeper of information, becoming the first person to receive any information pertaining to the project's design and construction. He processes the information, delegates responsibilities based on what needs to be done and works to maintain the "grand vision" of the project.

Secondary Roles:

The Structural Engineers – the structural engineers are in constant communication with the modular manufacturing team and report any changes, updates, and issues to the project's architect, serving as the official liaison between parties.

The Modular Manufacturing Team – the manufacturing team functions as the official interpreter of the architectural design into shop drawings for each module.

Design Complications and Challenges

Design complications and challenges can arise from having to deal with building structures that are not modular-friendly such as cantilevers, bay windows and roof decks. There is always a preoccupation with how to build these alternative structures, whether they present problems when considering overall modularity and thinking about the different materials that are required.

Most design complications arise during the interpretation of the different structural systems by the manufacturer and subcontractors, when the former is dealing with the design and fabrication of the modules and the latter with connecting the systems when the modules are being set onsite.

Revit®, a Building Information Modeling (BIM) software package was mentioned as a viable solution towards resolving the misinterpretation and misguided scrutiny of schematics and drawings by the GC, subcontractors, manufacturers and architects during the manufacturing, construction and setting phases. BIM software packages such as Revit® express drawings in 3D, which helps users account for the different "cuts" between modules and helps determine where systems connect and how, whereas with AutoCAD®, the drawings are limited to 2D, which makes them difficult to interpret when thinking of dynamic settings.

Subcontractors and Design

With 30 Haven, the contracts for the different subcontractors were awarded on a Just-In-Time (JIT) basis, making the process more fluid. In MCM, the architect and GC have to deal with a more compressed schedule, so drawings need to be kept flowing quickly enough, so that the manufacturing process occurs while the project is being designed. The subcontractors come as they are needed, but given the short timeline sometimes this means that the subcontractors have to come all at once. There is also more coordination up front to be efficient about understanding when the different subcontractors will be coming in. General procurement and the overall number of subcontractors are also reduced or sometimes eliminated depending on the amount of work that was already done in the factory.

Flexibility and Innovation

The LA gave us an insight into the potential innovation and flexibility that could become a future part of the modular construction industry, such as furnishing apartments with proprietary designs, to respond to changing market demands. Spaces could be rearranged so as to accommodate larger or smaller closet space as desired, instead of integrating closets from the beginning. Bedroom space would also be possible to manipulate with moveable walls, so large studios could become two bedrooms for a couple or a small family. This could be easily integrated into modules through smart architectural design and would serve as a marketing bonus to help sell the multifamily development. The main idea would be to incorporate flexibility so an end user can make decisions according to their unique tastes and lifestyles. The cost of the unit would be lower (there would be no additional cost for integrated walls, only for relatively simple mechanisms to make the walls moveable) yet in reality the units could be sold at a premium thanks to the innovation.

Module Manufacturer Profile: Keiser Industries

Keiser Industries, a modular manufacturing and construction firm, has been in the modular construction business for more than twenty years. It produces modules in an 80,000 square foot facility based in Oxford, Maine, and has historically played an important role as a single-family modular home supplier in New England, specifically in Maine, where they make up 17.5% of the single family housing stock in the state (40% of the total housing stock in Maine is modular) (Keiser Maine). In recent years, it has begun supplying modules meant for commercial RED, most recently for the mixed use commercial RED project, 30 Haven, based in Reading, Massachusetts. As a national leader in modular construction, Keiser has been at the forefront of providing quality homes to many clients, and has recently taken a step towards providing a greener and more energy efficient product. Keiser Industries has partnered with Kaplan Thompson Architects, to design and build "Maine's first and only 100% energy efficient new home community to homebuyers", based in Wells, Maine (Keiser Maine). Through smart insulation, special ceilings and triple glaze windows, a zero-energy status (NETZERO) will be achieved, where the energy savings can match the costs.

While Keiser continues to manufacture modules for the single family market, it has proven itself to be adept at producing modules for commercial RED projects.

Interview with Operations Manager

The Operations Manager (OM) for Keiser Industries provided us with the correct blend of technical and activity-based information concerning the process that is followed in the modular manufacturing facility. From this interview we were able to derive what exact tasks are required to manufacture a module, the distribution of tasks and drawings, the coordination of activities with external entities and lastly, how solutions are provided to eliminate inefficiencies and how to achieve the correct production balance. It became clear that the OM's responsibilities revolved around achieving the proper balance to reach the desired module production flow, through the intelligent designation of tasks to the correct labor team and the appropriate level of focus granted to whichever module needed it the most.

Since the module manufacturing process breaks up into design, plant management, lumber check, flooring, framing, component installation, priming and prepping, storage, and quality control activities, we made sure to make note of them, and ultimately constructed a DSM to illustrate their role in the overall manufacturing process as seen in Figure 17 in Chapter 6. Further explanation regarding the DSM's general functionality is given in Chapter 5.

The process that goes on in the manufacturing facility is mostly sequential and shows how the OM must deal with only certain line-of-production balance issues (e.g. the OM must iterate in the production of mockups as long as they're needed or demanded by subcontractors).

The following describes further detail concerning the distribution of tasks to the modular manufacturing operations team and the coordination of activities with external entities, as derived from our interview with the OM. For detailed information regarding the specific tasks following in the module manufacturing process, refer to the definitions for the different tasks in Glossary 2 and the MCM DSM detail in Figure 17.

Distribution of tasks to the operations team

The operations team is composed of the following individuals:

Foreman – responsible for the distribution of shop drawings to the lead men in charge of the following production phases: mill work cutting, flooring, wall setting, framing, component installation and priming/prepping. Also in charge of overseeing operations and reports directly to the OM. The foreman first gets a set of drawings from the CAD Technician, and then hands the drawings to the respective Lead Man for whichever production process needs them, with the specifications of what to do listed out in the drawing.

Lead Man – will have all the prints (shop drawings), and will have access to all the drawings to make sure that everything related to each production phase is in order. They will be relying on the workers (a mix of "Floaters" and "Specialists") to carry out the operations.

Head Engineer – the head engineer is in charge of overseeing the engineering drawings that were handed over from the developer's architect and engineering team, and works with the CAD Tech to have all the shop drawings handed over in a unified effort, avoiding the extra task of assigning different drawings to different engineers. The head engineer is in charge of supervising and monitoring the CAD Tech's shop drawings to ensure design application and quality.

CAD (AutoCAD) Technician – runs every shop drawing for the project, and is the single point person when it comes to the manufacturing design for every module in the project. He has control of any drawing that has been handed out, to whom and of any drawing that's left to hand out, as the project progresses. The CAD Tech reports directly to the Head Engineer.

There are two types of laborers who work at the modular manufacturing facility: Floaters and Specialists.

Specialists - specialize in performing specific activities, and usually focus on preparing modules for the specific production phase they are assigned to. There are specialists that only work on the flooring for the module, for example.

Floaters - are multi-purpose workers, who have the experience and flexibility necessary to easily perform any task related to the building of the module, whether the task concerns the sheeting, plumbing, carpentry or any other activity - during any of the production phases. Floaters are managed by the OM, lead engineer and head foreman, going to and from different modules and becoming part of the overall attempt to move and balance the line efficiently.

Coordination of activities with external entities

The manufacturer requires information regarding the project's design from the developer's architect and engineering teams (whether hired or in-house) to fully determine the final design and its transition into manufacture-ready modules via the manufacturer's CAD technician's shop drawings.

Coordination with Design Team – the developer's hired or in-house architect and engineering team will first agree on conceptual drawings for the project. Once everyone agrees on the overall design, the developer's engineering team then produces a set of drawings they plan to start the project with. The manufacturer then assigns a lead CAD (AutoCAD) Tech to produce shop drawings to be used for the manufacturing of the modules that very closely emulates the engineering drawings. When dealing with commercial RED projects, or unique, non-repetitive modular units, shop drawings are produced right before each module is produced, instead of having all shop drawings ready from the start. The manufacturer does this in order to keep the process flexible enough for the developer's design team and the manufacturer's engineers to make suggestions and provide changes, in an effort to ensure proper constructability and efficiency in design.

Coordination with Subcontractors – subcontractors are not normally incorporated in the project until the setting phase occurs, once the modules have already been manufactured and transported onto the site. Mechanical, electrical and plumbing services once on site are considered simple enough to install, although still subject to a learning curve, given the unusual circumstances subcontractors are faced with: having to connect systems between modules, module by module until the building is complete. More complex systems or specialized systems like unique fire prevention and HVAC systems require upfront coordination with the module manufacturer in order to prevent future complications. Early on, subcontractors have a "safety walk" at the manufacturing facility with the manufacturer's engineering and labor team to understand what the specifications for each module are and what the requirements for connections will have to be between the modules. The manufacturer is always incentivized to share information regarding the modules (whether it be through a "safety walk" or through detailed drawings) to avoid problems in the future. Mock-up modules that show the systems as they would be installed in the modules are also occasionally produced to show more than a drawing would. The modular manufacturer considers "buy in" from the subcontractors as a vital part of the process.

Balancing the Mix Line

While the modular manufacturer's operations management takes a big role in ensuring that the modular manufacturing process flows efficiently, modular production can still be disrupted by design errors, manufacturing mistakes and occasional change orders. Design errors can be manifested through misinterpretation of drawings; manufacturing mistakes can range from installing the wrong plumbing fixtures to installing the wrong electrical systems; and change orders can be complete residential unit redesigns or something as simple as changing a kitchen's layout. Any of these aforementioned problems can greatly affect the time the manufacturing process takes. Solving design and manufacturing errors requires the manufacturer to consider whether it would be wiser to resolve the problem in the manufacturing facility or onsite, depending on the situation. Change orders are always analyzed and as with any construction process, cost-estimated to understand what the developer will have to pay. However, the cost-estimation and potential time delays depend on *when* the developer asks for the change order, since the timing will determine whether the changes will affect the modules that are yet to be produced or the modules that have already been produced. If the modules have already been produced, the developer can opt for those modules to not be changed and as such, the developer only incurs the cost for the modules that will be coming down the line. Alternatively, the developer can request for the change order to affect everything, in which case, the cost will be higher.

A defined schedule, with deadlines, an official set date and a project completion date is defined before the manufacturing of the modules takes place, and should not be changed unless extraordinary circumstances (whether caused by an external event or a developer-induced event, such as a change order) require the change to happen.

Chapter 5: Introduction to the DSM and its Application to the Real Estate Development Process

Chapter Introduction:

Bulloch (2009) and Sullivan (2009) applied the Design Structure Matrix (DSM), an engineering systems model and framework, to the Real Estate Development Process (RED) in their 2009 MSRED thesis. This was the first time the DSM was applied to the real estate industry and to its development process specifically. After comparing the DSM to other models that have historically been used to describe the process inherent in the RED, the authors concluded that the DSM was the most appropriate way to map out the complex web of interdependent tasks that make up a RED (Bulloch & Sullivan, 2009). They subsequently compiled a complete list of the activities that make up a RED with information derived from interviews with senior managers from the global real estate services firm, Jones Lang LaSalle. Ultimately, Bulloch and Sullivan were able to build a normative "Baseline" DSM that mapped an optimal site built RED in its completion (Appendix 1), and were able to derive conclusions by comparing the "Baseline" model to other applications of the DSM that presented different scenarios that can occur during a development (e.g. market, political, economic or environmental changes). This chapter will introduce the DSM and its application to the real estate development process as derived from Bulloch and Sullivan's 2009 thesis.

The Design Structure Matrix (DSM)

The Design Structure Matrix (DSM) is a systems engineering tool that is used to map out, analyze and manage the complexity inherent in systems.

Figure 15 below shows an example DSM, as explained by www.dsmweb.org.

	A	B	C	D	E	F	G
A			X				
B			X	X			
C	X				X		
D	X						X
E							
F			X		X		X
G		X	X				

Figure 15 - A 7x7 DSM with both sequential and iterative tasks

The 7x7 matrix above denotes seven tasks that have different sequential and iterative elements. DSM's can follow two conventions: either FAD (Frequency above Diagonal) or FBD (Frequency below Diagonal). The DSM above follows an FAD convention, where rows represent what the task in question ***depends*** on, while columns represent what the task in question ***provides*** (FBD conventions are the opposite) (DSM Web). In this FAD convention DSM the rows have *feed-forward* information flows, which are sequential in nature, while columns have *feedback* information flows, which are iterative in nature (Bulloch & Sullivan, 2009). In this example, task C *depends* on information from task A and task E, and it *provides* information for task A, B, F and G.

A DSM can manage different types of data, ranging from Component-Based to People-Based, Activity-Based, and Parameter-Based, all meant to represent different relationships, such as Component, Organizational, Activity, and Design relationships between the data that is being studied. The aforementioned example from www.dsmweb.org represents an Activity-Based Process DSM, which can be applied to process improvements, project scheduling, iteration management, and information flow management (DSM Web).

The different applications of the Activity-Based Process DSM make it a perfect fit for applying it to the RED process. This was the specific type of DSM Bulloch and Sullivan applied to RED.

The Site Built Real Estate Development Process DSM

In an Activity-Based DSM, a process is studied to determine whether lowering the number of iterations and making the process as sequential as possible is the most cost-effective solution available. When thinking of RED, it makes sense that performing activities only once and getting them right the first time, would effectuate an ideal situation. Bulloch and Sullivan categorized the different tasks in a RED by grouping them under five main categories (see Figure 16 below (Bulloch & Sullivan, 2009)), four of which were based on Walter Graaskamp's (a real estate professor from The University of Wisconsin) RED Decision Making Process, and the fifth, "Project Management", was added as an additional category by the authors (Bulloch & Sullivan, 2009). The authors then organized the tasks by stage (see Appendix 1 for each stage as presented in Bulloch and Sullivan's Baseline DSM) to denote the different groups of related tasks that occur through the RED.

Figure 16 - Five Functional Sector Model

The groups or sectors in a real estate development process as defined above in Figure 16 will cycle through each of the sectors as a RED is analyzed and constructed (Bulloch & Sullivan, 2009). Each of these sectors is explained below:

1. Market & Competitive Analysis

This sector is where the developer looks at all the market conditions and evaluates the overall economy and capital markets. The developer will also examine the local market to better understand the demand for the product type, estimated rents, and the costs that will be incurred for the project.

2. Physical & Design

The developer looks at the various programing options in this sector. The design process begins, the massing studies take place, and the various consultants and outside contractors get involved. This is also the sector where the environmental studies take place, drawings get complete and construction documents are signed.

3. Political & Legal Analysis

This is the sector where the entitlements are explored and obtained. The developer evaluates the zoning and planning process and the necessary steps required given the local political environment. The developer also gets the approval of the public and other boards before the building and occupancy permits are obtained.

4. Financial Analysis

The financial feasibility and underwriting are performed in this sector. This ranges from the initial back of the envelope pro forma, through the final underwriting of the project. All debt and equity options are explored, agreements executed, budgets determined and rents collected. The decision to hold or sell the asset is also evaluated here.

5. Project Management

Bullock and Sullivan added this sector to the model to reflect the management of the process and the asset. All land opportunities and options are explored, schedules determined, organizational strategies discussed, and decisions to move forward or not are determined here.

Bulloch and Sullivan then mapped out a "Baseline" DSM that represents a normative RED process. While optimal behavior in an activity-based DSM might denote no iterations, the only phases of the RED where this is realistically possible are the Construction, Stabilization and Asset Management and/or Sale stages. The Idea Inception, Feasibility and Preconstruction stages are iterative in nature because they require tasks to be updated via feedback loops in order to proceed accordingly. It is logical that, for example, any development needs to revisit activities such as market analysis and conceptual design after having gone through subsequent activities in their respective RED stage.

The various stages as defined by Bulloch and Sullivan are listed below. For each project, the decision to move forward needs to be determined at the end of each stage. Most developments never move past stage one.

For additional detail on any of the stages or sectors please refer to Appendix 1.

1. Idea Inception

During this first stage of the development process, the developer is looking to "provide a product that meets a certain demand that he observes in the marketplace" (Bulloch & Sullivan, 2009). This stage is generally defined by one of two scenarios, a site looking for a use or a use looking for a site (Jarchow, 1991). This is the initial stage where the opportunity is looked at from a very high level and explored by the developer internally. He is looking to gain a general understanding of the development, including a financial view, potential restrictions (political or otherwise), zoning, and design possibilities (Bulloch & Sullivan, 2009).

2. Feasibility

Here the developer is looking to determine the highest and best use based on the information gathered during the idea inception stage. At this point the developer may begin to bring in consultants and other experts to help understand all the issues and what it will take to complete the project. This stage is not over until the highest and best use is determined and the financial underwriting provides the necessary financial feasibility data to meet the organizations' requirements (Bulloch & Sullivan, 2009).

3. Preconstruction

This process involves the design and development of the physical building, working through the various construction documents and the approvals necessary to begin construction. It is during this stage where the costs are further refined and the project timeline is established. The developer will also look to begin any preleasing and secure sources of capital in order to commence construction. As with all stages of in development process, the developer reaches a crossroads where he needs to make a" go" or "no go" decision. As the development gets further along the timeline, the decision to stop with the process becomes more costly as more time and money has been invested in the project (Bulloch & Sullivan, 2009).

4. Construction

Before construction can begin, the construction loan needs to be approved and funded. The developer will generally be required to burn through his equity prior to the first draw of the construction loan. The construction phase is where the contractors are responsible for constructing the building based on all the drawings and specifications that were finalized in preconstruction. This process can take many months or years and the financial underwriting assumptions must be revised, evaluated and updated throughout this stage (Bulloch & Sullivan, 2009).

5. Stabilization

The stabilization period is when the building is complete enough to receive a certificate of occupancy, tenants can move in and rents can begin to be collected. The underwriting will once again need to be updated to reflect the actual figures (Bulloch & Sullivan, 2009).

6. Asset Management and/or Sale

Once the building has been stabilized and the project is greater than 90% occupied (a 90% target might be ideal, but the developer will ultimately set their own occupancy target), the developer will look to replace the construction loan with permanent financing. If the building is for sale, the developer will turn it over to a building management or homeowner type association. If the building's units or space will be rented, the developer then needs to make the decision to sell or continue to operate the building. Some of the decision factors that go into this are the value of the property, the developers' business plan and financial objectives (Bulloch & Sullivan, 2009).

Findings and Conclusions

Bulloch and Sullivan were able to use the Baseline DSM they produced as an *optimal scenario* model to then manipulate and find out about the effect that (i) different types of information flows, (ii) modeling changes in the RED process and (iii) re-sequencing tasks in the RED process have on the Baseline DSM.

To model changes, the authors measured the effect economic variations and dynamic changes relating to the market, legal, financial and construction domains would have on the RED process. To measure the effect of different types of information flows, the authors coded the tasks into different categories, and as such were able to visually represent deeper explanations of the interactions between tasks. To re-sequence the tasks in the RED process, the authors created scenarios in which different tasks were assigned in different orders depending on what the developer wanted the desired outcome to be (e.g., designing before obtaining the appropriate entitlements) (Bulloch & Sullivan, 2009).

By producing a set of different scenarios that showcased different situations through multiple DSM models, the authors were properly taking advantage of the DSM's ability to visually represent the variance in the sequential and iterative relationships that make up the six different stages identified by the authors as part of the RED.

Bulloch and Sullivan were able to successfully apply the DSM to different scenarios and intelligently chose to model situations that are typical to most RED processes. From these different applications, they were able to conclude that the DSM is a useful tool that can promote a deeper understanding of the RED process and as such, help real estate developers deal with the complexity that arises from changes, whether desired or unexpected.

DSM Application (Bulloch and Sullivan DSM):

The DSM was utilized by Bulloch and Sullivan to better understand the RED process and the relationships between individuals and tasks. The structure of the DSM allows a user to understand where interactions occur in any given process and identify where the inefficiencies lie in a very simple and visual way. By simply rearranging the tasks, so there are fewer iterations, the process can be made more efficient and provide more direct input and sequential information flow.

Bulloch and Sullivan argue that the baseline DSM they developed should simply serve as a starting point to help a developer navigate a very complex process.

DSM Interpretation:

The Baseline Real Estate Development DSM developed by Bulloch and Sullivan (Appendix 1) is meant for a planned development and represents a normative or best-case scenario model. In reality, many tasks can change and different unplanned situations can develop. Due to the visual nature of the DSM, it is easy to see which informational flows are sequential (those below the diagonal line) and which are iterative (those above the diagonal) for a RED.

The tasks that show the dependence on other tasks are all within one of the development stages as identified by the authors. The instance where the information is iterative in this normative model indicates a planned iteration, meaning, an iteration that is to be expected. This is considered normative because most, if not all developments, have unplanned iterations (i.e. unexpected events) that occur.

Bulloch and Sullivan also noted that the interactions across disciplines occur very regularly. The different tasks require input from many disciplines that rely on each other to make the project successful. For example, in terms of functional roles in a development, finance experts don't know much about construction, but construction experts can still provide a great deal of information that the financial team can use to properly model and budget the RED's financial outlook.

Chapter 6: Real Estate Development Process DSM using Modular Construction Methods (MCM):

Chapter Introduction

As the construction industry evolves and the market becomes more sophisticated, more focus is given to alternative construction methods, in particular to Modular Construction Methods (MCM), a construction process where most construction-related tasks are completed offsite in a factory setting, instead of as is done traditionally, on-site. We have decided to take a closer look at the RED process that uses MCM by using the DSM to further understand how tasks completed off-site relate to those on-site and how MCM involves different information flows to those we see in site built methods. We will first highlight how the construction industry has integrated the manufacturing of building components offsite to provide more efficient building solutions to projects.

Components of the building process continue to be assembled offsite in greater amounts as the industry advances. Examples can be seen from items as basic as tile, and wood flooring. Tile will come in sheets ready to be installed, a move which saves time and money, while wood flooring comes prefinished, just requiring installation rather than the sanding and finishing that is required of traditional unfinished flooring. The preassembled pieces also range from high complexity items such as the plumbing components and piping behind the bathroom walls to the precast/prefab curtain walls of a high-rise building. Each of these items is assembled in a factory where greater tolerances can be achieved; they are produced more efficiently because they're assembled on a factory floor, and are manufactured by less expensive labor – a factory worker instead of a skilled tradesman.

An example of modular-type advances in the construction industry can be demonstrated through the relatively recent popularity in construction projects using walls which have "panelized", building components that are simply installed on site so a building can be framed and enclosed in a matter of days instead of weeks. Panelized building components refer to previously assembled components of buildings, such as walls, roofing and exterior materials that are manufactured off-site and are assemble on site. MCM is currently taking this modularity-based idea and raising it to a higher level, manufacturing modules that are more or less complete before they arrive on site, less a few of the finishes and MEP system connections that can be put together once they are set together.

All of these smaller advances have made the process of constructing new buildings and renovating existing ones faster and more efficient. In their effort to save time and money, developers and contractors have made MCM and modular-based construction methods more common place in the construction industry.

Modular construction will revolutionize the industry through its promise of speed and quality alone, even more so as additional developers realize the economic benefits from a time and quality perspective. As modular projects start competing effectively with site built methods for projects where MCM is more attractive, more cities and individuals will recognize the advantages of a modular project delivery system. Projects that profit the most from quick, quality deliveries, such as student housing projects (which would greatly profit from a timely delivery – completion before an academic semester begins) will start to become more modular based. Projects that involve high-rises and other more complex applications for MCM will also be experimented with, and will involve a learning curve, as would any other innovation.

Definition of Stages for Normative RED Process using DSM:

We have taken the Bulloch (MSRED 2009) and Sullivan's (MSRED 2009) thesis that concentrated on applying the DSM to site built methods and modified the development process as defined earlier into different stages and tasks, to adapt it to a normative RED process using MCM. The prior thesis served as a solid starting point for a DSM that details a normative development process - we have added the appropriate tasks that are unique to modular construction. The complete listing of these tasks is in Glossary 1.We have also reformulated the RED process as defined by Bulloch and Sullivan to take into account the differences that exist between both construction methods. After identifying the different tasks via interviews with senior management from both the manufacturing and development sides of the business, we further broke the tasks into the Graaskamp stages defined in the previous thesis, specifically adding "Factory", "Site Preparation and Module Set" and "Site Work and Complete Construction" stage. The stages are defined and listed below:

1. Idea Inception

This stage is where a project is evaluated at a very high level. When a development idea is conceived it is either an idea for a use that needs to find a site or a site that has been identified that needs to find a use. In order to evaluate the investment idea a market and feasibility analysis needs to be completed and the zoning and political environment needs to be explored. The approximate timeline needs to be established and the investment thresholds for the organization need to be determined to decide if the back of the envelope pro forma analysis meets the organizational strategy.

This is the stage where construction options should be first analyzed and explored and where the decision to build modular or on site needs to be initially determined. Because the MCM process requires so many iterations early on in the process (since the developer, GC, architects, engineers and manufacturer will be starting to work together), it is critical to determine the feasibility of modular to make the decision to pursue that route early.

Again, these items only need to be looked at from a high level to determine if the investment thesis is valid and if it is worth exploring further.

Iterations are required in this stage to evaluate whether the project fits the investment criteria for the developer and whether the project can be completed modularly. Some of the key factors in determining the feasibility of a modular project include the site layout and physical restrictions of oversized loads arriving at the project and if the development only passes the back of the envelope analysis if it is completed modularly. *Is there a higher and better use for the site that cannot utilize modular construction?*

Other things to consider include the time required to complete the project and the local zoning and political environment. Will variances be required for the land opportunities and given the political environment, will the variances be easily obtainable? Will the market support the highest and best use, as determined at this stage, or should the project scope change and be expanded or constrained?

There are many idea and investment opportunities that never make it past the idea inception stage and that number is reduced even further when the feasibility of modular construction becomes part of the evaluation criteria. As the market stands today, modular construction is in most cases, most appropriate for multifamily housing up to five stories. Other uses require longer uninterrupted spans and modular steel construction has yet to make the technological advancements required to make it commercially feasible.

2. Feasibility

Once the project has passed preliminary financial analysis and the developer's approval, a more detailed exploration of the project is needed. The developer will perform a more thorough analysis of the market, to truly understand the zoning and environmental issues the site might face. The developer will also begin evaluating contractors and consultants.

The developer will take all the information gathered thus far and determine the highest and best use (HBU) for the property and will reevaluate whether to go before the zoning board and apply for relief. This is also the stage where the design and programing for the project officially begin. These items need to be worked through with the external stakeholders and the strategy will need to be revisited once the main potential issues are identified.

One of the big differentiating points for MCM lies in this stage. **To have a project run smoothly, integration across developer's and modular manufacturer's teams is essential.** Getting the manufacturer involved early in the design stage allows the team to understand the limitations of MCM and work around them effectively. By doing this, many potential "rework" design iterations can be eliminated because the team understands the process early on.

Due to the heavy design and programming element in this stage, there are many planned iterations. However, there are many unplanned iterations as well due to the increased planning that is involved in modular construction. Refer to Figure 18 and notice the tasks above the diagonal line for the Feasibility stage as well as those above the diagonal line and outside the stage "box". The former tasks are the planned iterations, while the latter tasks are the unplanned iterations. The different planned and unplanned iterations per stage will be further defined in Chapter 7.

3. Preconstruction

Once the project is deemed feasible and the developer decides to move forward with the project, the project reaches a more involved stage for all parties. The preconstruction stage involves working out the details on how to bring the project to market (financially and with public approval), getting the correct estimates from top contractors, and finalizing the project's budget.

During this stage, drawings are completed and financing for the project is also secured. Ideally, the developer will also prelease some of the space, which reduces the overall risk of the project early on.

The modular manufacturing process also adds a few additional steps to the various stages, especially early on in the process. The drawings need to be approved by the state agency, in Massachusetts this is the Board of Building Regulations and Standards (BBRS). The manufacturing facility will then build to those specifications. For a traditional site built project many of the decisions, especially the design, can be made "on the fly" once the project is up and running. However, with MCM many of these decisions need to be made early on in the process. **The biggest item that is decided early on is the set date. Both the manufacturer and the contractors work backwards from this date to complete the modules and have the site ready to receive the modules.**

Contractors are responsible for making initial bids and the schedule is determined during this stage. All the financial information has been reviewed and is finalized during this stage as well. The initial IRR and investment hurdles should have been determined by this point, it is at this stage where those calculations are refined based on the schedule and timing of the project and those assumptions are taken to various equity and debt providers. There are likely to be multiple iterations required to ensure the external stakeholders are happy with the process and project. The developer should be concerned about keeping the citizens of the community content, a process that requires numerous meetings, design reviews and negotiations.

4. Factory (4a)

The factory and site work stages are what would otherwise be considered the construction stage for a site built project. This is where the workers begin assembling the modules in the modular manufacturing facility. The design team, if needed takes a "factory walk" with the developer and subcontractors to showcase what the modular design will be like, highlighting the different builds and connections involved through a mockup, which provides information to the different parties, which might want to make any last minute changes, if needed. These changes can include but are not limited to changing light switch configurations, window returns or choosing different colors/finishes for the modules.

4. Site Preparation & Module Set (4b)

The site work is run in parallel with the factory work. It is the responsibility of the GC to have the site ready to receive the modules, to then be able to set them in a limited period of time once the factory is ready to ship them. This is the stage where the time savings associated with MCM come into play and can either make or break the project. If the project is not delivered on time or within a reasonable window that is relatively similar to the original deadline expectation, the underwriting will be negatively impacted and may change the entire return and distribution expectations for the project's investors.

Both of the start dates and on-going schedules are determined by the module set date which is determined in the preconstruction phase. The modules need to be completed in the factory while the site is being excavated, utilities connected, foundation poured, and structure completed so it can receive the modules. The schedule is a determining factor in this stage because the modules have a limited life when they sit in storage. While the module is sealed and weatherproofed, the materials used are temporary. Therefore, the longer the module sits before being installed, the greater the likelihood of damage occurring.

5. Site Work & Complete Construction Work

This is the stage where the MEP systems are connected across the modules and to the main connections. The remaining interior finishes are completed within the units and the hallways or other unfinished areas are prepared for building occupancy. The exterior siding is installed and the remaining site work is completed. The underwriting is updated based on the final construction figures and the building is ready to be turned over from the GC to the owner.

All the contractors need to know or learn how to construct in a “non-traditional” method. The subcontractors are connecting the MEP systems are learning the nuances of how to complete modular buildings while the modular team is learning to work with the new subcontractors. These processes are critical to the success of the project and getting the certificate of occupancy. Executing the MEP systems connections properly results in a more rapid building completion.

6. Stabilization

The stabilization stage is where most of the ongoing building operations occur. There are some final items from the construction stage that need to be completed, such as obtaining the permanent certificate of occupancy and completing the construction punch list. The stabilization stage deals with leasing all available spaces, having tenants begin paying rent as soon as possible, and properly managing the building.

7. Asset Management and/or Sale

This stage is similar to the stabilization stage, where the building is under ongoing operations and management. However, this stage also involves taking a closer look at the long term plan for the building and the organization’s strategy. Evaluating the capital markets, putting long term financing in place and selling the property are all part of this stage.

While the aforementioned stages are very similar to those defined by Bulloch and Sullivan, the Factory and Site Work stages refer directly to key differentiation factors that make MCM a unique and different process when comparing it to a traditional site built method.

We conducted interviews with the senior management (the developer, lead architect, GC and OM for the modular manufacturer) involved in the 30 Haven that also have extensive experience with modular construction. We identified the tasks associated with the modular development process and put them in chronological order as described by the team.

DSM Application, Interpretation and Optimization:

At first glance the application of the DSM to an RED process using MCM seems very similar to the application to traditional site built RED as produced by Bulloch and Sullivan in their thesis. However, there are clear differences between them. Glossary 1 highlights the additional activities involved in an

RED process using MCM, and Figure 18 shows the different distribution for both planned and unplanned iterations in the DSM for RED using MCM.

While the application of the DSM for Bulloch and Sullivan's traditional site built development was meant to develop a normative model for an RED process, the application of the DSM in our case was meant to not only develop a normative model for an RED process that uses MCM, it was also meant to highlight the relationship between MCM and RED, or in more technical terms, the relationship between a manufacturing-based process and a more traditional construction-based process. The DSM was able to highlight how the parallel work between the manufacturer and the site construction teams is planned for and becomes a key part to balance and coordinate as the project progresses.

The resulting DSM from this process has proven to be highly iterative, as would be expected in any RED process. While many of the iterations in and RED process using MCM are planned, there are multiple areas within the stages we identified that are unplanned and are situated in the stages that occur before the project is fully completed (Yassine & Braha). Addressing unplanned iterations normally requires developers to either re-sequence the activities or create new ones (minimizing the impact of the unplanned iteration or eliminating the unplanned iteration altogether).

For full detail concerning the process, its analysis and optimization please refer to Chapter 7.

Overall, the stages are very similar to those defined by Bulloch and Sullivan in 2009, but the Factory and Site Work Stages are the key differentiation points for modular construction. When the construction of a site built project begins the other items can't be initiated until the site is ready for the next stage to occur. Currently, the fastest and most efficient way to erect a building is to utilize up/down construction. In this case the foundation is poured first. Once the foundation is poured and stable, the steel or concrete structure begins to go vertical while the basement and parking levels are built out. This simultaneous activity helps save time in the construction process.

Modular Manufacturing Process DSM:

The DSM analysis for the RED process using MCM covers the whole manufacturing process as only one activity (Begin Manufacturing of Modules, activity 402a). While this thesis is focused more on the RED process and how MCM factors into it, it is still important to understand the stages and components that make up the process for the manufacturing of the modules. The importance in understanding the module manufacturing process lies in comprehending MCM's capacity to rapidly manufacture modules and have them completed by a specific set date.

To construct the MCM DSM we identified the following stages and activities that directly surround and happen within the manufacturing process:

Site:

Activities: Foundation Construction, Utility Connections

Factory:

Design, Plant Management, Lumber Check, Flooring, Framing, Component Installation, Priming and Prepping, Storage, Quality Control, Mockups

Transportation:

Obtain Proper Permits by State, Arrange Drivers and Escorts, Determining Onsite Storage, Onsite Oversize Load Issues

Site Work and Complete Construction Work

Select Site Crew, Select Site Crew (Subcontractors), Set Modules, Secure Modules, Weatherproof Modules, Perform Interior and Exterior Finishes, Connect all Utilities, Airtight Testing, Final MEP Inspections, Final Approval, Obtaining Occupancy Permit

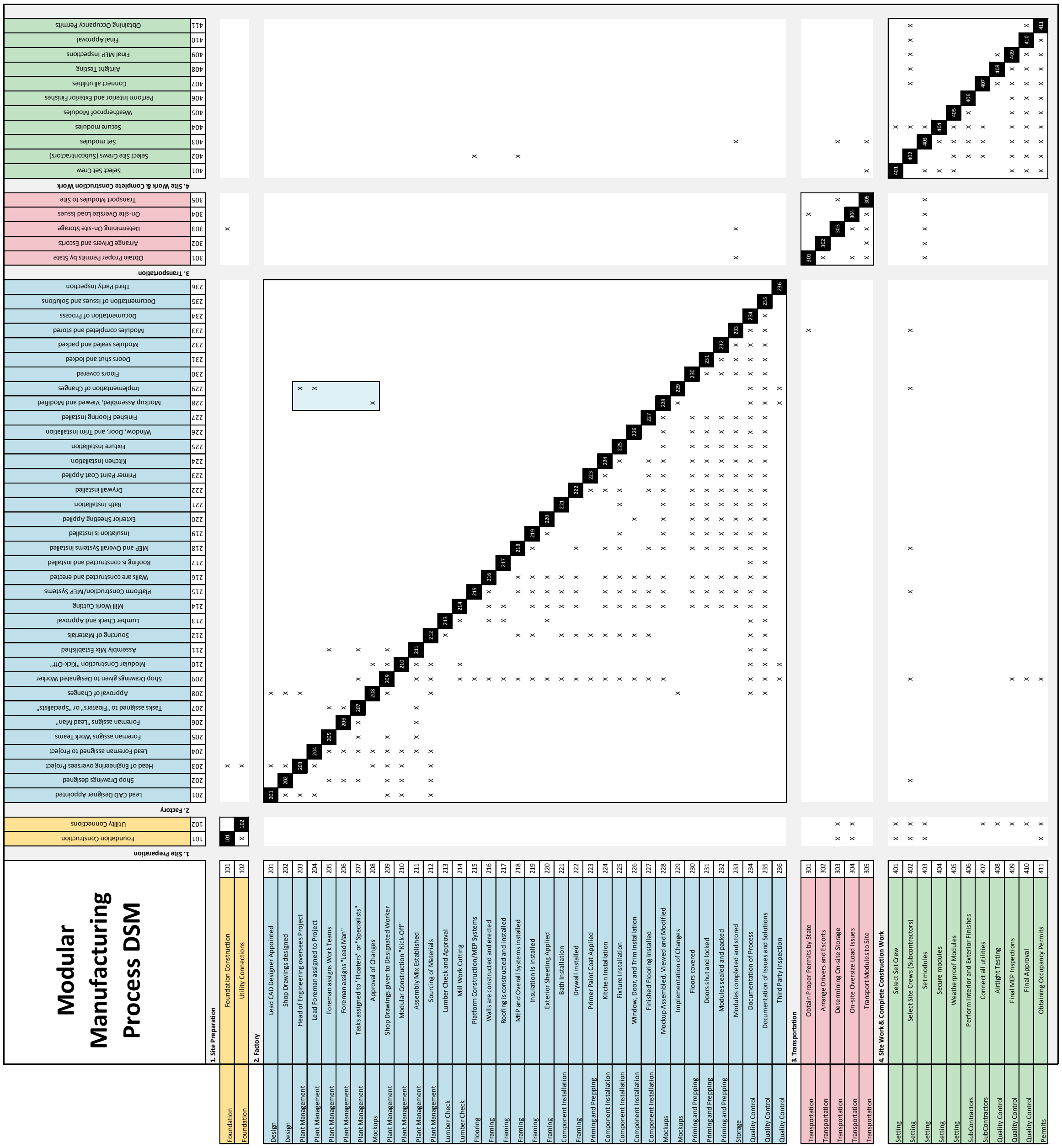

Figure 17 - Modular Manufacturing Process DSM

Figure 17 above shows how the factory stage has only a few planned iterative loops during the beginning of the stage, where the design-based activities (task 201 and 202) and the plant management delegation activities (task 205, 206, 207 and 209) iterate as the design for the modules is finalized and the head of engineering, lead foreman, module work teams and “floaters”/”specialists” are assigned to different modules for each production cycle. The rest of the tasks in the process are sequential, only becoming iterations once more when the mockups are assembled, viewed and modified (task 228) by the appropriate plant management (task 203 and 204), and finally approved (task 208).

The remaining stages surrounding the factory stage give further insight into the roles the manufacturer assumes once the modules leave the factory. The transportation stage shows how selecting the set crew (task 401), who is responsible for setting the modules on site can cause unplanned iterations. Together, the set crew and the GC's workers on site can cause unplanned iterations for the transportation stage and the setting of the modules (task 403). In theory, this should not happen, given that modules will only be transported if the site is ready to receive them. However, these and the other few unplanned iterations surrounding the stages beyond the factory stage show how MCM's factory stage is the most sequential and controllable process.

The controlled environment of the manufacturing facility and the linear production process MCM follows is demonstrated clearly in Figure 17. These data will prove to be insightful when the MCM process is added to the broader RED process in Chapter 7.

Chapter 7: DSM Process Analysis

Chapter Introduction:

As explained earlier, the DSM is a systems engineering tool that helps identify inefficiencies in a given process. It does this in a simple and visual manner by mapping out tasks and showing their interactions. This chapter will identify and provide a deeper analysis of the task interactions, iterative processes and potential unplanned events that occur in a RED that uses a modular construction process. The chapter will highlight those iterations that are planned and will discuss them in a broad manner. We will identify the unplanned iterations in the process and also explain why these occur. Chapter 8 will discuss the various ways a developer can manage these unplanned iterations.

Overview of the Development Stages

The RED process, in essence, functions through information sharing and revisions based on information gathered throughout the process. As an example, going through the design process after performing a zoning analysis can result in financial underwriting that cannot justify the investment required. This entails going back and redesigning a project to meet the underwriting requirements in place. It also means potentially going before the zoning board to ask for zoning relief. The design would then need to be approved by the zoning board and the community which may involve multiple rework activities by the project's architect, with a few visits to the town meetings and other community-outreach venues to work towards the public's approval of the project. These are typical politically charged events in a development and often necessary steps in making a project happen. We identify these types of activities in the DSM model as planned iterations. Planned iterations provide valuable information to the process and improve it at each step.

After mapping out the processes of a RED project utilizing MCM we identified a number of areas in the different functional stages during a project's timeline that require iterative processes to occur, some in areas where traditional site built would require less. Many of the iterations are planned and occur earlier on in the development process (as in the example above) prior to large funds being invested in the project. While any additional iteration adds time to the project, the general time savings of four to six months that are usually seen when using MCM is ultimately the result of constructing much of the project within the confines of a modular manufacturing facility in parallel with the required site work being completed. The reduction in the amount of time required to deliver a completed building to market offsets the increase in time required by the additional iterations in a modular development.

We look to explain the stages particular to an RED process that uses MCM and the events that occur within these stages. We then pinpoint the planned iterations that occur at each stage and that we have identified as unique to MCM.

Identification of Planned Iterations

We will complement Chapter 6's broad overview of the different stages in the modular development process; the following will go into more depth regarding the planned iterations that occur in the various stages. Some of these iterations are similar to the traditional RED process, but many are unique to the RED process that uses MCM, especially early on in the development when planning and decision making is critical. We will be referring to specific task interactions in the DSM and the stages (by number) they correspond to below, to denote the different planned iterations in the RED using MCM process.

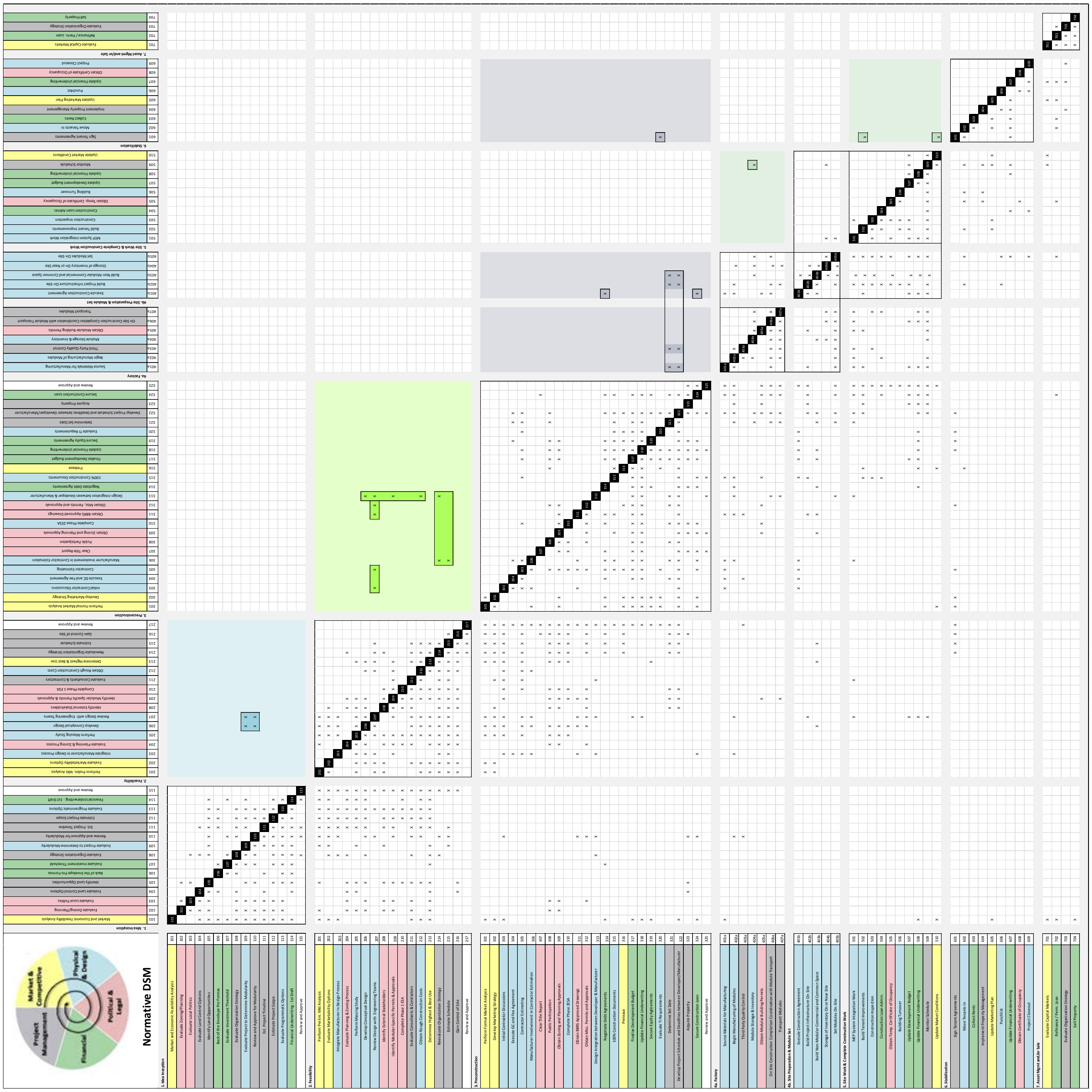

Figure 18 - Normative DSM

1. Idea Inception (1), Feasibility (2) and Preconstruction (3) Stages:

For the planned iterations in these stages, please refer to the space above the diagonal and within the Idea Inception, Feasibility and Preconstruction stage limits, denoted by lines that form a box that enclose the stages (see Figure 18).

While **the idea inception stage** has multiple planned iterations, which in theory should take care of defining the project's design and modularity, the iterations occur so early in the RED process, that the developer will most likely choose to move on to the coming feasibility and preconstruction stages. During the idea inception stage there is too little time and money invested in the project to cause the developer to not continue. These subsequent stages not only have more planned iterations, which can help mitigate potential design errors and help integrate the different parties involved in the process; these stages are also, according to our findings, more critical to the development process. We have found that investment during these stages is greater and the decisions at these junctures become thus more critical to the success of the project. The idea inception stage will have the developer iterate extensively through the evaluation of land opportunities (task 105), the organization's strategy (task 108), the evaluation and review of the project for modularity (task 109 and 110), and the project timeline/scope (task 111 and 112), to get a good idea of whether the opportunities that are being considered for the RED project will be feasible for the organization. The identification of land opportunities (task 105) is a task that is heavily iterative, since every other task in the idea inception stage needs to be clear on *where* the project will take place to determine the schedule, financial returns and modularity for it.

The feasibility stage involves assessing the market conditions, the as of right zoning ("as of right zoning" refers to the zoning uses that are currently in place and are thus immediately found to be allowable under the local zoning code), and the various players that will be involved in the process. The different players that become part of the process at this point include the project design, manufacturer and city planning teams who, in unison, become moving parts for the developer to coordinate, by fulfilling their needs while fulfilling those needed for the development to move forward. The initial drawings first need to be completed to get the proper approvals and to understand the rough construction costs. These physical and design based activities all involve getting feedback from the project's contractor and respective consultants, especially once the conceptual design is developed (task 206) and initial contractor discussions commence (task 211). The developer will assess the information, and iterate with the evaluation of the consultants and contractors (task 211), obtaining rough construction costs for the project (task 212) and determining the highest and best use for the project (task 213), and which will update the project's general development process and activities. Once the activities are adequately refined and updated, the project needs to go through another internal assessment, after which an organization-based feasibility decision (task 214), needs to be made to ensure the project makes economic sense and meets the investment criteria of the organization before moving onto the Preconstruction stage. Once the project heads into **the preconstruction stage**, the real estimating, public participation, financing, and construction documentation decisions need to be made and finalized. There are, for example, planned feedback loops between the financial analysis activities (finalizing the development budget (task 317), updating the financial underwriting (task 318), securing the equity agreement(task 319)) and the activities that determine the political situation, the proper timeline and the project's final costs (determining the set (task 321)/schedule dates (task 322) ,finalizing the contractor estimations (task 305), executing the GC agreement (task 304), obtaining the public's participation (task 308), the correct permits and approvals (task 309, 311 and 312)). All these decisions and activities derived therefrom have an effect on the project's projected returns, its schedule and the final set date for the modules. The project then officially becomes "real" and the external factors and stakeholders, such as the political entities, financiers and active shareholders now play a stronger role in the development. As such, the public's opinion and the project's capital sources can now have a major effect and can make or break the project at this stage. The iterations and feedback loops between the developer and these parties are essential for the development to get the approvals, financing and capital it needs. **Correctly and effectively taking the information obtained from the various external sources is critical in making the project a reality.**

It is clear that the success that lies in moving the process along is dependent on the successful integration of the various players in the development process. MCM requires most of the important design, financing and political approval decisions to be made upfront, and also requires that all of these decisions occur concurrently in the feasibility and preconstructions stages. Successful integration between the developer, the design team, the manufacturer, and the GC provides a more seamless flow of information between parties, which reduces the frequency of feedback loop iterations and the need to go back and forth between multiple-party based decisions and designs. The different project teams involved become fully aware of the requirements MCM has thanks to the manufacturer's work on defining these requirements early on. The manufacturer also works to meet those requirements in these two preconstruction stages so as to avoid design changes and iterations in the future, which can considerably delay the project.

2. Factory (4a), Site Preparation, and Module Set Stages - Parallel Tracks (4b):

For the planned iterations in these stages, please refer to the space above the diagonal and within the Factory (4a) and Site Preparation and Module Set (4b) stage limits, denoted by lines that form a box that encloses the stages (see Figure 18).

The activities that take place in the factory and on site occur in parallel and account for much of the financial and time savings that MCM provides. MCM can eliminate four to six months off the development schedule in a commercial RED multifamily project. By manufacturing the modules, and working on the finishes at the factory while the site is being excavated, the foundation is being poured, and the site infrastructure and utilities are connected, the developer profits from MCM by saving time and reducing the overall carry cost of the project.

The planned iterations in these stages occur to achieve an effective parallel-work process that is followed between the on-site crew and the manufacturer to make sure the construction schedule and process runs smoothly. These stages need a constant feedback loop to occur between the GC on site and the manufacturer to ensure that the schedules are coordinated. The manufacturing process is in a controlled environment and faces little production delays, which helps make much of the parallel work between the manufacturing facility and the site timely and possible. While sourcing materials can be an issue, there are generally material substitutes readily available and of such quality, that using them would not have much of an effect on the design or quality of the construction. However, the site work can potentially run into many delays. As the process continues, the GC may run into environmental issues that need to be addressed or might face geological obstacles that require extra time to work around. Complaints from the surrounding neighbors may also slow down the construction process. Delays might also be occasioned by the local utility companies hired to perform the required site connections. If a mixed use MCM project, for example, requires steel for the first floor retail component and the fabricator doesn't deliver the product on site quickly enough to erect the steel, then the final set date for the modules may have to be pushed back.

The planned iteration space for these activities is located in the space between the factory (4a) and the site preparation and module set (4b) stages, within the confines of the space that encloses both stages. The factory stage's activities (task 401a, 402a, 404a, 405a, 406a) are couple with the site preparation and module set activities (task 401b, 402b, 403b, 404b and 405b), with the exception of the third party quality control activity (task 403a), which is independent of the parallel tracks and timing that go on between the manufacturing that occurs in the factory and the construction on site.

The list of potential setbacks that can occur in the construction stages is expansive, thus requiring constant communication between the GC and the manufacturer to ensure that the modules are produced in an orderly fashion, this way helping reduce the amount of time they sit idly on the site. Given the limited life of modules and the necessity in keeping them in near-perfect condition it becomes necessary to ensure damage prevention and to avoid extra repair costs that may be incurred if they sit on site too long and become damaged.

3. **Site Work and Complete Construction Work - MEP Integration (5):**

For the planned iterations in this stage, please refer to the space above the diagonal and within the Site Work and Complete Construction Work (5) stage limits, denoted by lines that form a box that encloses the stage (see Figure 18).

The MEP Integration and final site work is essential in completing the project, primarily because the modules are just "lone boxes" until they are connected completely, not only structurally, but also via the systems the building needs to function. The connections for the MEP systems that occur on site are not completely obvious to most subcontractors who have to perform them, and as such, the GC for the project will most likely face a subcontractor LC phase. During this LC phase, the subcontractors will have to work alongside the manufacture's site crew, who might be setting modules while the subcontractors work on modules that have already been set. The subcontractors will have to study the different MEP and specialty system connections the modules have, and will then work to understand how to complete the connections between modules.

This project stage involves minimal planned iterations between the GC, subcontractors and manufacturing site setting crew, and in theory, the whole process should be simple enough to have only a few feedback loops occur between parties. However, according to our interviews with the GC for the 30 Haven project, a typical RED project that uses MCM does not have an MEP systems integration process that flows as smooth as the developer would ideally like it to be. The reality is that the project schedule can be delayed if the contractors are not up to speed and familiar with the modular construction process. Delays here can severely affect the underwriting and the final delivery date of the project.

The bulk of the planned iterations for this stage occurs between the MEP systems integration work (task 501) and the tasks that need to be completed before the project can be stabilized (mainly – the construction inspection (task 503), obtaining the temporary certificate of occupancy (task 505), updating the development budget (task 507), and updating the financial underwriting (task 508)).

Identification of Unplanned Iterations

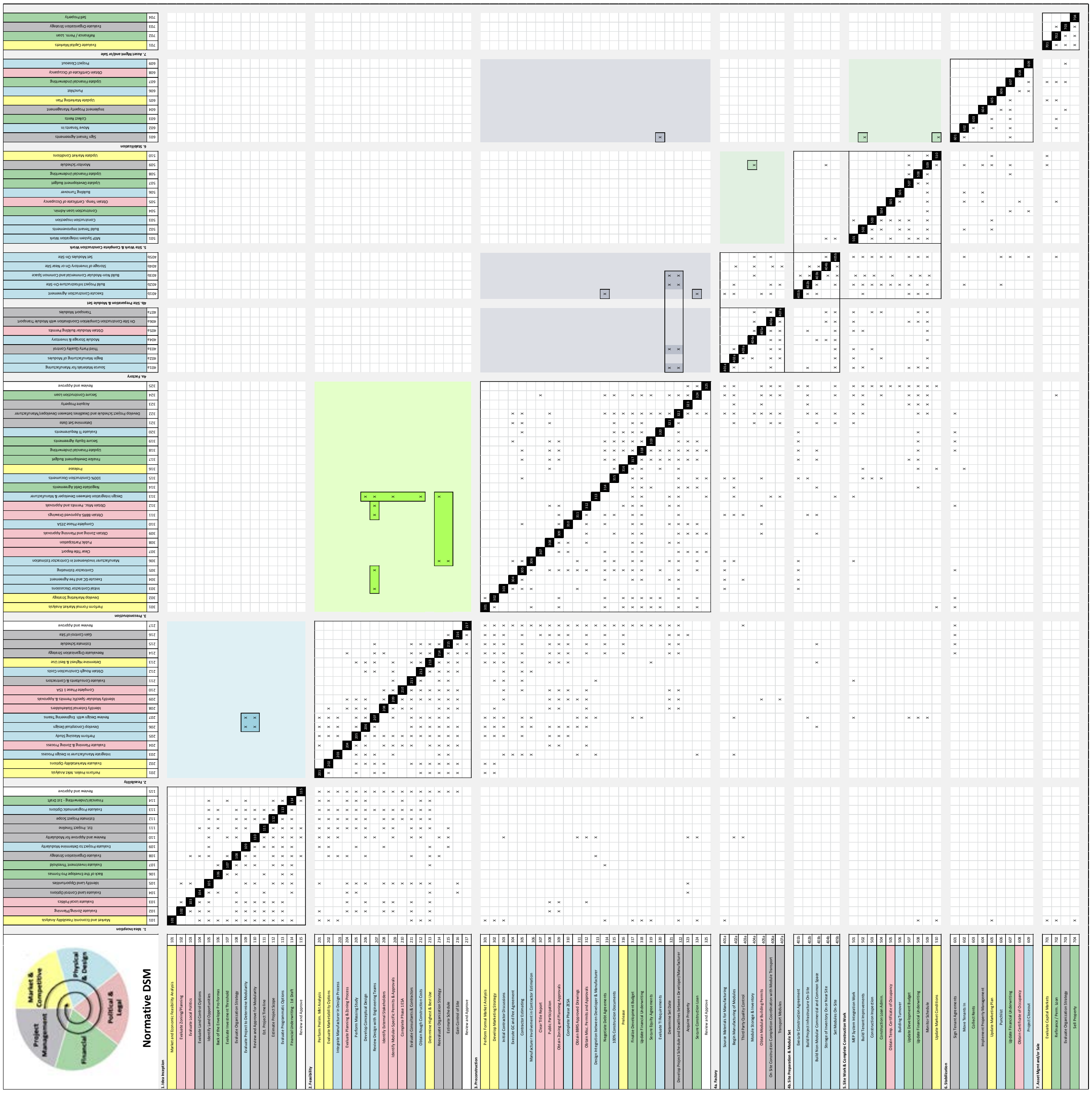

Figure 19 – Normative DSM with Failure Modes – the shaded spaces outside the stages hold the unplanned iterations for the DSM

The term “Unplanned iteration” refers to the feedback loops that are unintended, and that, in most cases, cause negative disruptions in the process. These iterations cause delays in the process and can become very costly. Unplanned iterations can be identified in the DSM model by looking at the task interactions that occur above the diagonal line and fall outside of the “process box”.

We have identified a number of unplanned iterations in the modular development process that are unique to modular development. We have noted these unplanned iterations by the stage they correspond to and grouped them according to the stage of the development they affect the most, as seen in Figure 19 above.

There are four different unplanned iteration groups:

1) **Determining Modularity through Design**: these unplanned iterations occurs between the idea inception and feasibility stages, and concern activities that focus on reviewing and determining the project's modularity based on the updated conceptual design and the design review that occurs between the developer and manufacturer's engineering teams in the feasibility stage.

2) **Project Definition**: these unplanned iterations occur between the feasibility and preconstruction stages. The design review activity in the feasibility stage goes through various iterations when reviewed by the contractor, public entities and manufacturing team. This all affects the organization strategy and schedule.

3) **Project Delays – Preconstruction:** the unplanned iterations occur between the preconstruction stage and the factory/site preparation and module set stages. The unplanned iterations relate to the manufacturing and site work activities that in theory need to occur synchronously. Delays in any of the activities related to both the manufacturing factory and site construction activities cause changes in the module set date and final project schedule.

4) **Project Delays – MEP Integration & Construction Completion:** the unplanned iterations here should be limited, given that there is a strong emphasis on MEP integration work being performed satisfactorily during the planned iterations between the factory/site work and the site work completion stage. However, project delays could still occur between the site work/construction work completion stage and the stabilization stage, whose "sign tenant agreement" activity relating to the project leasing can be delayed if the building's TI requirements and updated market conditions have not been met.

Each of these stages is critical to the successful completion of the development and construction processes. In this chapter we look to identify and explain the failure modes that take place during the whole development process. By "failure mode" we refer to any grouping of activities that makes any part of the development "fail" functionally, inasmuch as the process "fails" in those unplanned iterations occur and consequences (e.g. delays and cost overruns) result.

In Chapter 8 we will propose solutions that describe how to reduce the number of unplanned iterations and make the RED process more efficient.

1. The following explains where these unplanned iterations occur in the DSM's different development stages. **Idea Inception - Determining Modularity Through Design:**

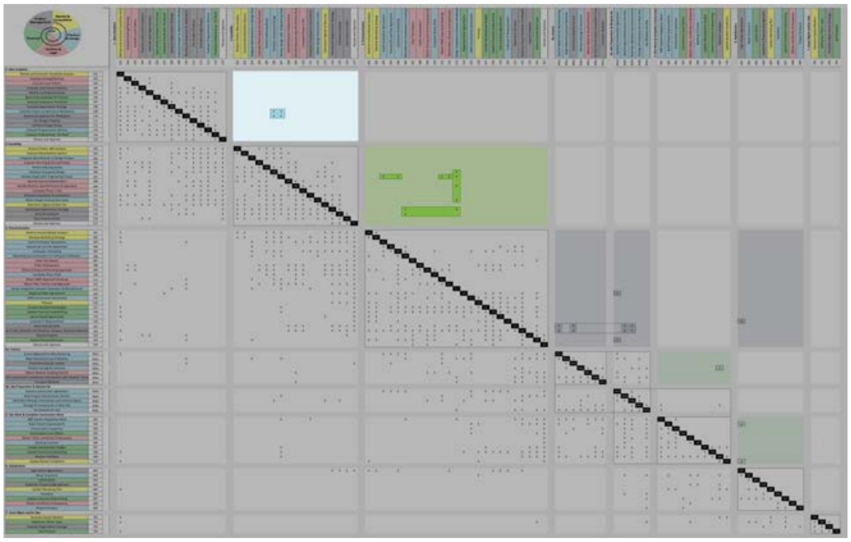

Figure 20 - DSM highlighting unplanned iteration for Idea Inception Stage (1)

Figure 20 is referring to the unplanned iterations that occur in the area above the diagonal, beyond the idea inception stage limits. The unplanned iterations occur between evaluating and reviewing the project for modularity (task 109 and 110) and developing and reviewing the project's conceptual design with the developer and manufacturer's engineering teams (task 207 and 208).

Determining if a project will be constructed modularly is a decision that the developer needs to make at the very beginning of the development process. If the developer is inexperienced or has little knowledge of the modular process, the decision can be made to move forward modularly, when in reality the project might not be suited for modularity. The developer will generally first make these decisions early in the process, without necessarily relying on the input from designers, modular manufacturers or GC's. The nature of the early stages of a development generally don't allow for communication with parties who provide essential RED services unless the organization in question is large and vertically integrated. While any project can technically be completed modularly, the project loses the efficiencies derived from MCM if the developer has to compensate the construction process with additional work to make up for what modules can't achieve (e.g., complex designs and in the case of stick-built, the ability to build skyscrapers) which then makes site built construction become the logical choice. If the developer moves forward on a modular basis and uses an architect that is not experienced with modular construction, delays will also occur due to construction reworks and improper initial design.

The unplanned iterations that happen during this stage deal with the evaluation and approval strategy for modular construction in the Idea Inception Stage. The iterations deal with the conceptual design and their continual review with both the manufacturer's and developer's engineers in the Feasibility Stage. The developer generally refrains from bringing in external players prior to getting the engineering and design teams involved, which contains these iterations between the first and second stage in the development.

Problem Statement: If the developer fails to integrate the engineering and design team completely with the manufacturer's design team, the developer will face issues with the design of the building, which will cause the developer to re-evaluate whether the project is more efficient using MCM or site built methods.

2. Feasibility – Project Definition:

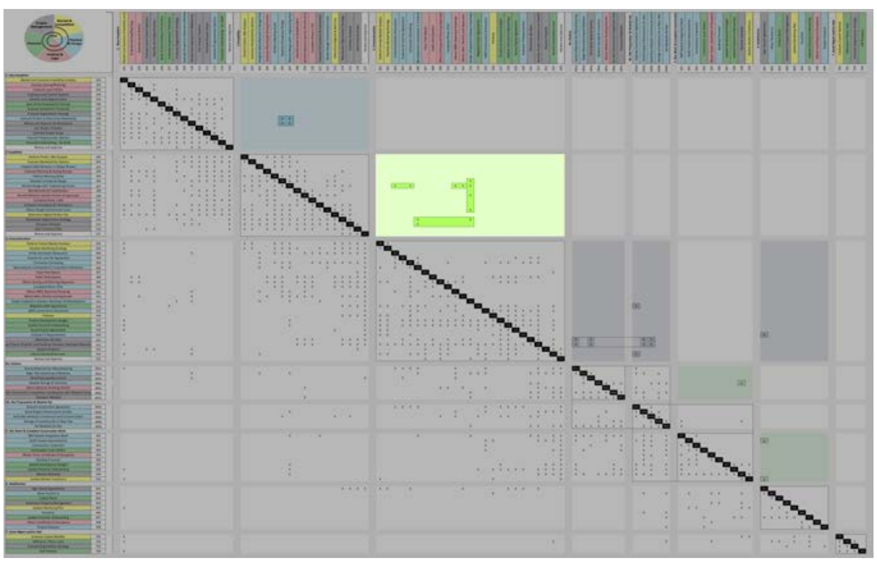

Figure 21 – DSM highlighting unplanned iteration for Feasibility Stage (2)

Figure 21 is referring to the unplanned iterations that occur in the area above the diagonal, beyond the feasibility stage limits. A series of unplanned iterations occur between the review of the project design with the engineering teams (task 207) and the contractor (task 303 – initial contractor discussions, task 305 – contractor estimating), the entities that grant the permits and approvals (task 311 – BBRS approvals, task 312 – misc. permits and approvals) and the design integration efforts between the manufacturer and developer (313). The latter task also can have unexpected events occur between the contractor, permit and approval entities, and the organization itself when it reevaluates its strategy.

Feedback loops, in part fed with what happens with these activities directly affect the reevaluation of the organization strategy (task 214) and the estimation of the project schedule (task 215).

The Feasibility stage holds plenty of opportunities for unplanned iterations in conjunction with the Preconstruction stage, given the numerous external parties that start integrating and becoming part of the development process during these stages. By the end of the feasibility stage, the developer is looking to have the project's official final design finalized. However, the financial, political, GC and design entities involved in the Preconstruction stage can cause delays when weighing in on the design, financial and approval process, which results in additional iterations that were not originally planned.

Problem Statement: *Estimating* (Referring to task 207 interacting with task 303 and 305) - The engineering and design teams for both the manufacturer and developer need to ensure all drawings are clear and complete. If they are approved, yet still inadequate, the contractor and manufacturer will most likely produce a range of incorrect estimates when they look at the drawings and first attempt to estimate the cost of the project. The range of estimates will need to be revised when further revised, because of the design's lack of clarity and completeness. The scope of work needs to not only be complete before moving onto the Preconstruction stage, it also needs to be correct – the identification of errors is not always guaranteed, regardless of how "obvious" they might be.

Problem Statement: *Approval* (Referring to task 207 interacting with task 311 and 312) - The Permitting and Approval process is a stage that is beyond the control of the developer. This stage may result in a number of unplanned iterations before the BBRS (Board of Building Regulations and Standard) or the local building department approves the drawings, depending on the nature of the project and permitting entities involved. However, approvals granted by the BBRS should be relatively easy to obtain if the manufacturer is involved early on and the architect and engineers are familiar with modular construction and the standards associated with it.

Problem Statement: *Design and Schedule* (Box 3- Referring to both task 313's interaction with task 206, 207, 209, 212 and 214 as well as task 306's interaction with task 214 and 215) – The project's schedule and the development firm's general organizational strategy is also affected by the involvement of the manufacturer and developer's design teams and their effort to integrate successfully. As mentioned, if the project design is not complete and the manufacturer and contractor proceed regardless , the probability for rework is increased. Unless this back and forth is worked into the schedule prior to it occurring, the rework will result in considerable schedule changes and the potential abandonment of the project due to schedule delays. The project is also at risk if the market conditions, which may change or suddenly deteriorate, are not completed on schedule. The organization would then have to consider a reevaluation of the project to then choose whether to continue pursuing the development.

3. Preconstruction – Project Delays:

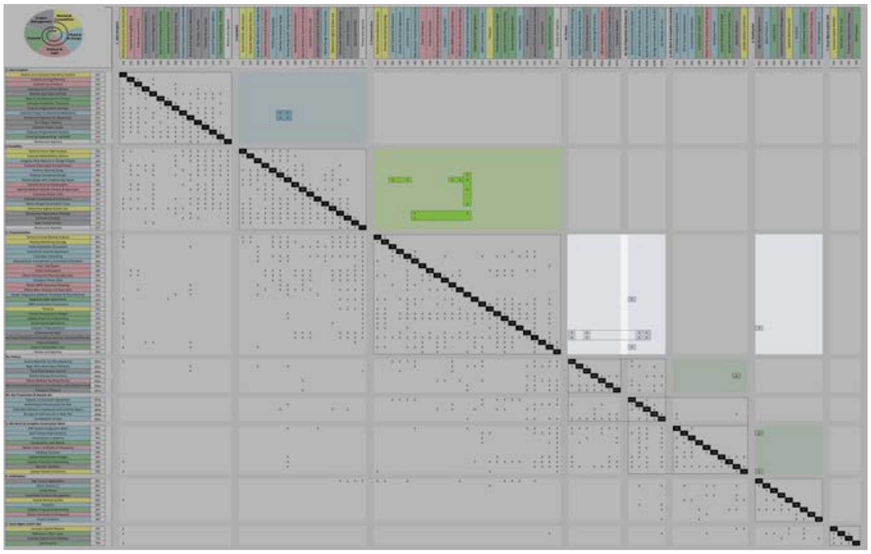

Figure 22 – DSM highlighting unplanned iteration for Preconstruction Stage (3)

Figure 22 is referring to the unplanned iterations that occur in the area above the diagonal, beyond the preconstruction stage limits. A series of unplanned iterations occur mostly between the activities for the determination of the set date/finalizing the project schedule and deadlines (tasks 321 and 322) and activities at the factory stage (task 401 – sourcing materials for manufacturing, task 403 – third party quality control) and at the site work stage (task 502 – build project infrastructure on site, task 503 – build non-modular commercial and common space). There are also select activities that can form feedback loops, yet are idiosyncratic (explained below) to most developments (most notably: executing a GC agreement: task 314 & 501 – negotiating debt agreements and executing GC agreements, task 324 & 501 – securing construction loan and executing GC agreement. Evaluating TI requirements (task 320) and signing tenant agreements (task 601) is an unplanned iteration that occurs because a tenant fit out will not occur until a tenant signs a lease.

The Preconstruction stage is where the schedule is determined and finalized. However, there are many events that can occur during the construction process which can result in changes to the schedule.

Problem Statement: The set date for the modules should ideally be determined in the Preconstruction stage as early as possible so the GC and manufacturer can work backwards to determine the corresponding development-based activities' lead times as necessary.. Each activity and the unplanned iterations that can result from time mismanagement will potentially vary the dates in which site construction and factory work will commence, so detailed scheduling must be carried out at this stage.. Ideally, the set date should not change once it is determined, but in practice, the date does change, as small changes compile and become delays, as can happen, when for example, key suppliers deliver materials late or when an extended period of bad weather affects the initial site work. Considerable delays can obviously surface if there are site work problems; the modules will not be set and the building completion date will have to change.

Problem Statement: There is a unique dichotomy that occurs in the preconstruction stage: the developer has to either execute the construction agreement to get financing from the bank, or has to get the financing from the bank before a contractor is willing to execute a construction agreement. This is a risk that all developers face, which depends on the project in question, as well as the business preferences the bank and contractors wish to employ. Some banks may require a GC agreement to be in place while others may not. Some GCs may require financing to be in place while others may not.

Problem Statement: The budget for tenant improvements needs to be determined in the preconstruction stage. If the leases are not executed for the commercial tenants during this stage, an estimate can be used, but the exact figures will not be determined until the agreements are executed.

4. Factory, Site Preparation and Module Set, and MEP Integration and Site Work and Construction Work – Project Delays:

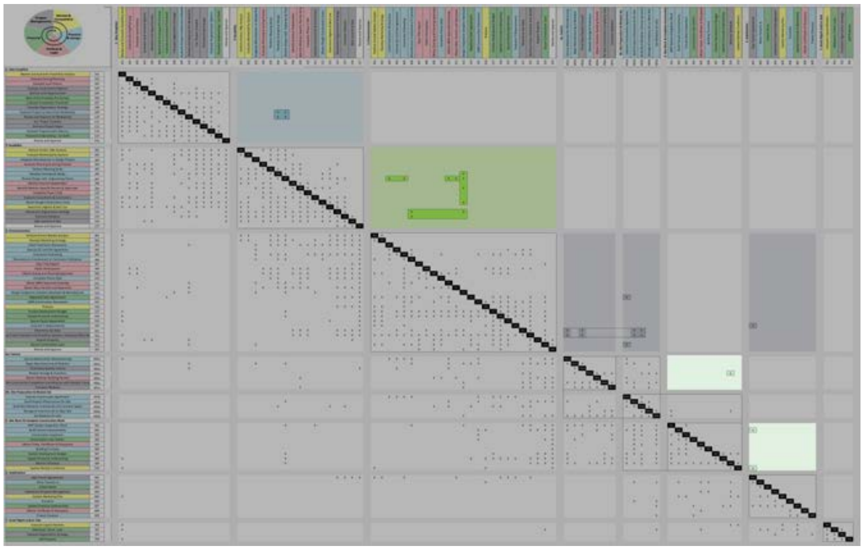

Figure 23 – DSM highlighting unplanned iteration for Factory (4a), Site Preparation and Module Set (4b), Site Work and Complete Construction Work (5)

Figure 23 is referring to the unplanned iterations that occur in the area above the diagonal, beyond the factory, site preparation/setting and construction completion stage limits. There are only three unplanned iterations that occur between these stages. Modular storage inventory (task 404a) can engage with the monitoring of the project's schedule (task 509) if the parallel tracks between the stages have the modules sitting idly in the manufacturing facility because of any unforeseen delays. The other two unplanned iterations that may occur concern signing tenant agreements (task 601) and two tasks that can delay this activity directly, both tenant related and impossible to not have as feedback loops given the nature of developments and acquiring tenants (task 320 – evaluating TI requirements and task 502 – building tenant improvements)

The construction of the building occurs in a few phases, of which, the factory and site preparation phases run in parallel. The work in the modular manufacturing facility and that which is performed simultaneously on site will require feedback and constant communication between the different parties involved. Once the modules are set, MEP integration will take place, and if done correctly, will lead to construction completion. Maintaining the schedule and avoiding delays cannot always be prevented, given the complexity that lies in maintaining flow during the parallel work stage, dealing with different subcontractors coming together for the MEP integration, and all the while upholding the highest levels of quality control on and off the site. Unforeseen circumstances can sometimes result, which gives way to unplanned iterations.

Problem Statement: The manufacturing schedule for the modules needs to be updated and adjusted based on the feedback concerning the activities on site as carried out by the GC. If delays occur on site, the manufacturing of the modules may end earlier than expected, which will result in modules being stored on the job site for longer than planned. The modules will then be subject to weather conditions and will rapidly deteriorate if they are not set in less than a week.

Problem Statement: The tenant improvements cannot be completed until the tenant lease agreements are executed. If a tenant has not been found by this point, it is economically unfeasibly to build out a final retail space as the exact needs have yet to be determined. There is an unavoidable unplanned iteration at this stage, which is very hard to circumvent given that most retail tenants are signed on after the space is done.

Chapter 8: Failure Mode Solutions

Chapter Introduction:

Chapter 7 described the failure modes and unplanned iterations per development stage we identified through the DSM analysis of a normative RED process that utilizes MCM. In this chapter we will provide proactive and applicable solutions for the aforementioned failure modes and unplanned iterations, to produce an optimal DSM model. We suggest multiple solutions that explain how to best achieve the desired result and make the process more efficient. We will specifically focus on solutions that either minimize the likelihood of unplanned iterations and their effects or completely eliminates then. In some cases the failure modes and iterations cannot be eliminated, in which case we still identify and explain the intricacies involved in these failures, address why they cannot be eliminated and clarify what their role is and how all these factors contribute to the uniqueness in an MCM process. The opportunity for unplanned iterations to arise can, however, be minimized, as well as their impact, with proper management of the process.

Definition of Optimal Model and Failure Mode Solutions by Development Stage:

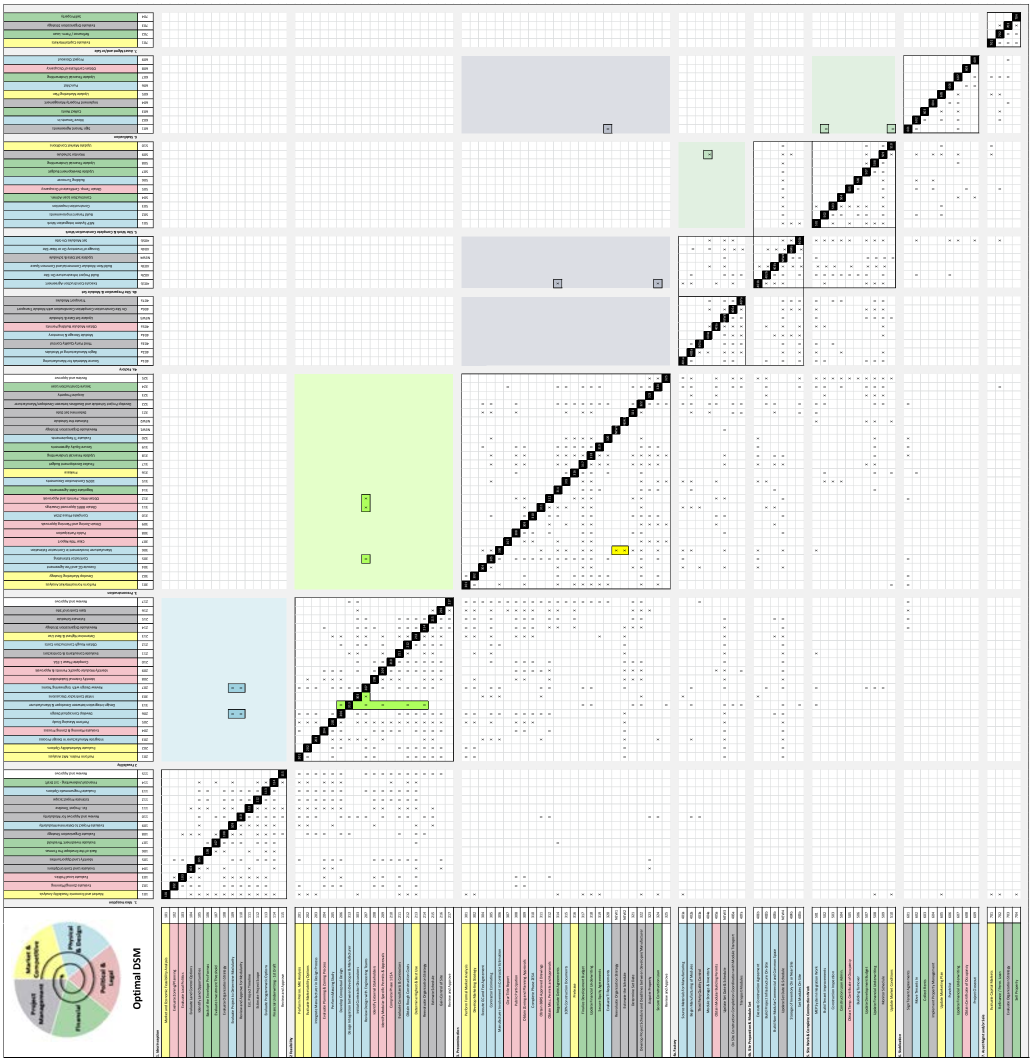

Figure 24 – DSM highlighting unplanned iteration minimization and elimination-based solutions

1. Idea Inception - Determining Modularity Through Design:

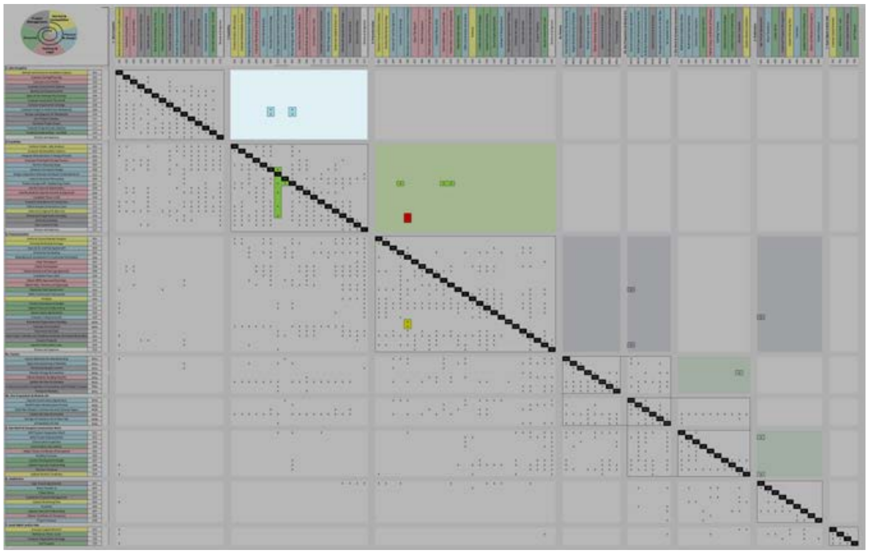

Figure 25 – DSM highlighting unplanned iteration solution for idea inception stage

Solution: By **integrating the manufacturer early in the process** many of the design iterations can be minimized or eliminated.

By executing task 203 (Integrating the manufacturer in design process) well the probability of a success design is greatly improved. This can occur by having the manufacturer designate a "lead person" who will work with the developer and will ensure any and all changes to the design are made efficiently, which means, having all necessary changes occur within the idea inception change, instead of having to rework them later. This avoids the iterations detailed in the green box above. Having a single point-person be the responsible party for the project's design, makes any design modification more digestible for the architect, helps build a relationship and also furthers the integration of the different parties. The lead person knows the driving factors that can avoid future iterations, and works to implement them to determine the project's modularity early on. All these efforts make for a more efficient process and will lead to the risk that lies in having future design iterations occur.

The manufacturer can also preempt design rework by having a set of standardized designs for multifamily and commercial development products that use MCM. The design for these standardized products would be pre-engineered and deemed to be commercially viable, in an effort to eliminate a lengthy approval process with the BBRS. These actions, if successful, should reduce the time required for a full set of building permits. Having standardized designs to use for commercial RED projects that use MCM is comparable to the single family home product designs offered by most modular manufacturers. Offering a basic product design sheet to either start with or choose to follow completely to the developer also allows for exterior customization and dimensional changes that are standard for a multifamily product. Given multifamily products are generally sixty to sixty-five feet in width, but vary in length, the manufacture can adjust the building design to allow for site and zoning restrictions.

The risks of having to rework design can also be minimized easily for a developer that already has experience in modular construction. The developer can also profit from having a team that understands modular design well. While the process for RED using MCM is significantly different from a traditional site built project, having an internal expert will pay dividends to the developer in the long run.

2. Feasibility – Project Definition:

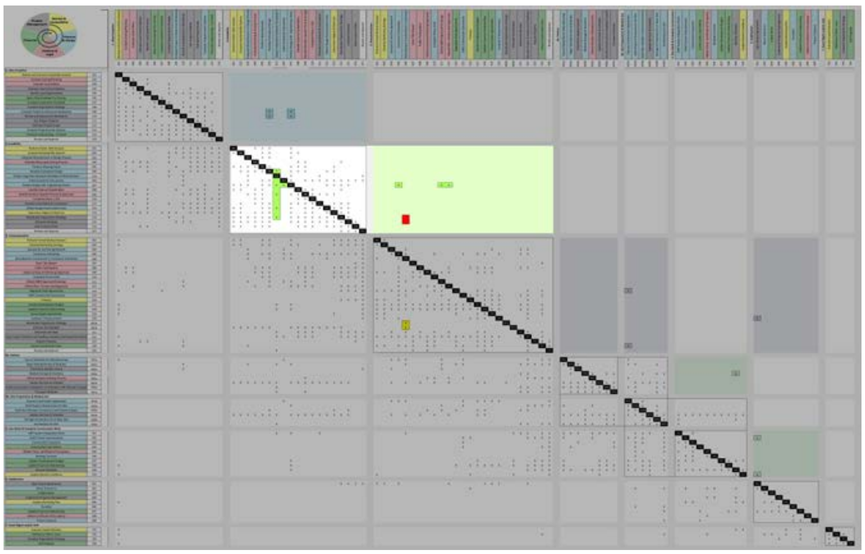

Figure 26 – DSM highlighting unplanned iteration solution for feasibility stage

Solution: *Estimating* (Referring to task 207 interacting with task 303 and 305) - **Early involvement with the contractor** will generally result in not only more accurate pricing, but will also cause the contractor to possibly suggest alternatives that could work for a developer's needs for construction materials and services, most preferably at a reduced cost. The process will be more efficient by having the contractor partake in defining the pricing expectations upfront.

Meeting with the contractor and revising the finalized drawings with the developer needs to happen early on in the process. To do this we will re-sequence activity 303 (Initial Contractor Discussions) and will move it to the feasibility stage. Time spent on this activity should decrease given how there is now a planned iteration for it, regarding a design review. Potential issues further along the process are thwarted, which also saves time in the long run. While the contractor estimation risks are not eliminated, the probability of these iterations happening unexpectedly is reduced.

Solution: *Approval* (Referring to task 207 interacting with task 311 and 312) **- Iterations will be avoided in this stage if the correct staff and CAD Technician (the manufacturer's lead designer, in charge of translating the project's engineering designs into shop drawings)is assigned to the project**. The designs should meet all the standards of the BBRS and local building codes, however if the local building department is unfamiliar with the process, the approvals may take a little longer due to their lack of familiarity with the modular process.

Properly executing the public participation aspect of the development will help ensure there are no public pressures to hold the project up. Marketing the benefits of the development to the community will help guide the approval process for the project and will also reduce the likelihood of community backlash that could delay the approval of permits.

By moving tasks 303 and 313 (Initial contractor discussions and Design integration between developer & manufacturer) between task 206 and 207 (Develop Conceptual Design and Review Design with Engineering Teams) the risks associated with having design issues via incorrect contracting estimates manifest are further reduced. The BBRS feedback loop can also be minimized and even eliminated if the manufacturer properly assesses the project's timeline and is fully aware of the required iterations necessary to comply with the BBRS.

Solution: : *Design and Schedule* (Box 3- Referring to both task 313's interaction with task 206, 207, 209, 212 and 214 as well as task 306's interaction with task 214 and 215) - The process to fully integrate the manufacturer and developer's design teams can become more efficient if it is coordinated by a single person. One point person is generally more effective in minimizing the likelihood of design rework since changes to the design can get lost and misplaced if too many players are involved in the project's management and approval process. The project management piece that happens between the feasibility and preconstruction stages involves multiple activities moving in parallel. The best solution comes from re-sequencing these activities, having them occur earlier in the process, to make the process more sequential and planned out, all the while maintaining the parallel nature of the activity.

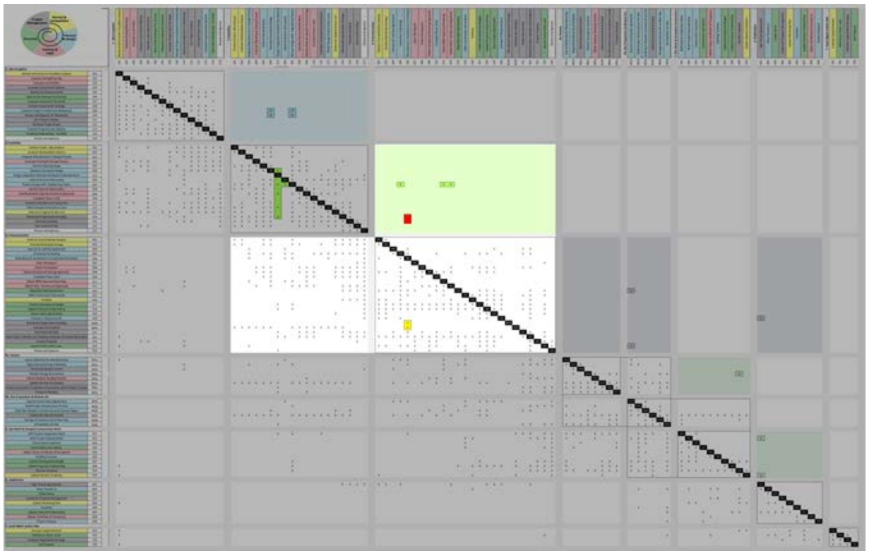

Figure 27 – DSM highlighting unplanned iteration solution for feasibility stage

Solution: By additionally creating a set of tasks in the preconstruction stage, one in which the organization reevaluates its strategy and the other in which the developer can update the schedule regularly, the development will do these tasks sequentially, instead of re-iterating between the stages. The iterations thus become less likely to occur early on in the process.

3. Preconstruction – Project Delays:

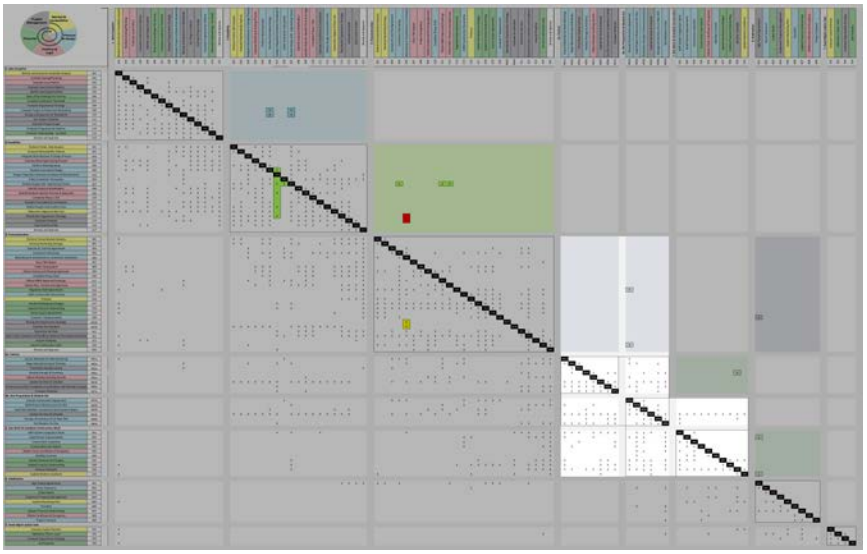

Figure 28 – DSM highlighting unplanned iteration solution for preconstruction stage

Solution: The preconstruction stage presents numerous occasions for delays to occur. **Sourcing material delays** can be addressed by having the procurement department at the manufacturer order items in advance to properly ensure they are in stock and ready for distribution on a Just-in-Time basis. This will eliminate some of the risk that comes with material delays. Additionally, if there are problems with the supply for any particular product, there are usually many substitutes available. The GC should also be prepared for the procurement of materials used on site as these can be more difficult to obtain and are not as easily substitutable. By having alternative suppliers the contractor eliminates some of this risk. Unplanned iterations for **the project's schedule and set date** can be avoided by adding a task called "Update Set Date & Schedule" in the preconstruction stage. As a result, this simple addition becomes a planned event and a sequential activity.

Third party inspection problems, while a potential issue, should, in most cases, be avoided, in large part because the modular manufacturer of choice is expected to build a quality product that meets the standards of the agreed-upon drawings and those imposed by the BBRS. Higher efficiencies and quality should be achieved in MCM, given that the building occurs in a factory (i.e., in a controlled environment). Any delays should be incorporated into the project schedule when the manufacturer commits to a set date.

Coordinating the factory work and site work is a critical to meeting the originally planned set date. Without coordination and proper communication between the manufacturing and site work crews, the modules will potentially be sitting idly on the job site for days or, to their own detriment, weeks, before the actual set date comes. As mentioned, modules stored outside a controlled environment pose a huge risk for the project, given their limited life and easy exposure to bad weather and potential vandalism. All problems relating to site work should be addressed by the GC before the module's set date, to ensure that the modules arrive in a Just-In-Time manner and are then promptly set and hoisted by the cranes on site.

The execution of the construction agreement and the construction loan that will be pursued to finance the manufacturing/construction phase of the project will depend on the project and the contractor/financing parties involved. In order to avoid potential delays, caused by either the contractor requiring the loan to be secured or vice versa, the developer should be aware of the bank's and contractor's requirements to proceed accordingly.

Determining estimates for the Tenant Improvements (TI's) can be done early on from a budget perspective, but the actual work, and therefore the actual costs cannot be completed and estimated until an actual tenant has signed a lease. Depending on the strength of the rental market, the landlord may need to increase the TI allowance beyond the original budget to secure a tenant. In an ideal situation the tenants are preleased and the build-outs can be completed during the construction stage. In practice, most retail tenants, who are likely to require TI's, will only sign a lease after construction, meaning that the developer will have to bear this cost in the future, only successfully thwarting it through a TI allowance.

4. MEP Integration and Construction Completion – Project Delays:

Stages: 4a – Factory, 4b – Site Preparation & Module Set, 5 – Site Work & Complete Construction Work

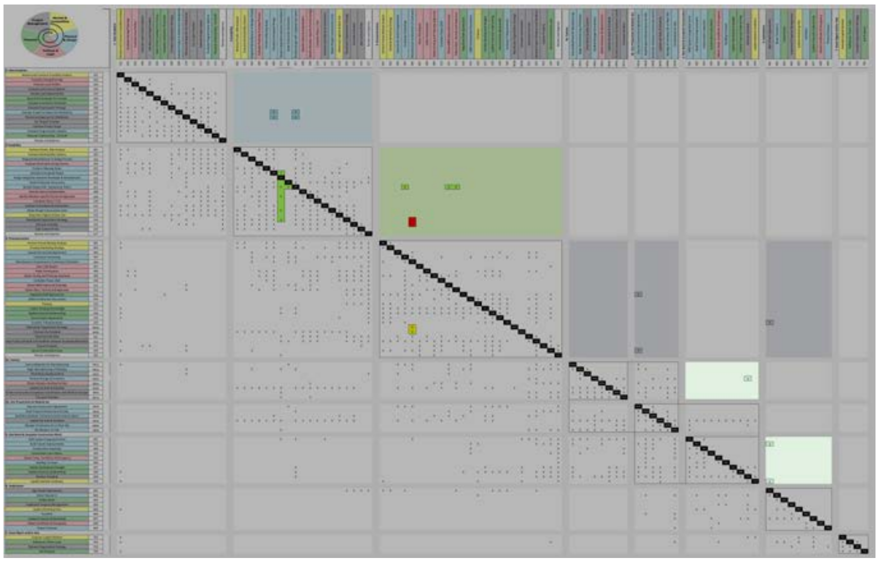

Figure 29– DSM highlighting unplanned iteration solution for preconstruction stage

Solution: Both the manufacturing schedule and the TI issues can be avoided through preliminary planning, as detailed in the solutions for the preconstruction phase. **Of dire importance however, is making sure that the MEP systems integration flows smoothly.** Even though the MEP systems integration activities are planned iterations, too many iterations can be just as harmful, and potentially even more so, than most unplanned iterations. Close attention must be paid to the MEP systems integration planning early on, to preempt any future incidents. The manufacturer's site setting crew, the GC's on site labor, the multiple subcontractors working on site en masse from day one and the quality control inspection teams all need to "be on the same page" in order for the modules to be set and connected in the correct way.

Chapter 9: Financial Analysis

Chapter Introduction:

This chapter introduces the financial analysis component for the DSM and the failure modes that arise in a RED process that uses MCM. We developed a hypothetical baseline pro forma for a 60,000 square foot multifamily modular project located in suburban Boston. We looked at the costs and potential impacts of the various failure modes in the normative modular DSM (Figure 18). We compared these failure modes to the optimized DSM (Figure 19) and completed a second analysis to illustrate the potential financial impact of a more optimized process for the development in question. While we could have completed a comparison of the returns for a modular and site built project, we believe that there has already been thorough research and analysis completed on the subject. Cameron and Di Carlo's prior analyses have focused on the time value of money and the idea that modular construction saves time in the overall construction process (Cameron & Di Carlo, 2007). We took into account the current capital markets and consequently employed assumptions in the model that reflect the suburban Boston suburban multifamily RE market thereby providing an unbiased reflection of the potential impacts discussed earlier in this thesis.

Financial Analysis Goals:

The main goal of this analysis is to show how the inefficiencies and unplanned iterations in the development process can impact the returns for a given project. We specifically look at the IRR and NPV functions, both levered and unlevered, for the baseline financial scenario and compare these to the scenario that models the normative DSM, and the scenario that models the optimal DSM. The normative DSM financial analysis scenario accounts for the effect of time and additional costs represented by the unplanned iterations in the normative DSM. The optimal DSM financial analysis scenario accounts for the decrease in total time and costs, as represented by the elimination and minimization of unplanned iterations in the normative DSM. We measure the deviation in IRR and NPV from the baseline scenario to each of the DSM scenarios presented. Our intention is to show how developers financially model any given RED scenario, to produce an ex ante measure of potential returns. We will highlight, how a developer's ex ante projections can be incorrect and disproportionately high, given the unplanned iterations that can occur, as well as the additional time and costs associated with a development. After modeling the returns for the optimal DSM, we have found that the returns are actually lower than in the baseline scenario. We determined that a possible way of avoiding this situation is by relying on a adequate contingency budget or having the RED project completed and leased before originally scheduled (thereby saving money through time).

Financial Analysis Methodology and Description:

We developed a baseline financial proforma for a hypothetical multifamily development that utilizes MCM in suburban Boston. This type of development is closely represented by 30 Haven, the project we analyzed in our research. The hypothetical RED is modeled after the most probable type of commercial real estate to be potentially developed in the Northeastern United States using MCM. Currently, the Northeast (NE) utilizes MCM using traditional timber framing methods. The Northeast region generally uses timber construction because of the resources and labor expertise in the area. Due to the transportation restrictions of modules, traditional regional building methods are generally utilized when using MCM. This limitation is due to resource availability, construction expertise, and the regional investment in modular manufacturing technology, which, in general, has yet to expand into using steel. While the technology necessary to make use of steel in MCM exists, the NE region has yet to make general use of it.

Financial Assumptions and Baseline Scenario:

The baseline pro forma we developed is for a fifty unit, 60,000 square foot multifamily development project with a standard set of assumptions and investment returns which are listed below in (Table 2).

General & Scheduling Info	
Total Square Feet	60,000 sf
Leasable Sq Ft	51,000 sf
Site Acquisition	2,750,000
Closing Costs	2.00%
Vacancy Factor	5.00%
Project Kick-Off	Month 1
Construction Start	Month 6
Construction Finish	Month 18
Lease Up Start	Month 16
Lease Up Period	8 Months
Free Rent	0 Months
Avg Unit Size	1,025 sf
Total Units	50 units

Income & Expenses		
Market Rent		$39.00 psf
Rent Growth Rate		3.00% /yr
Construction Costs		0.00% /yr
Hard Costs	$11,100,000	$185.00 psf
Soft Costs	$2,775,000	$46.25 psf
Additional Delay Costs	$0	$0.00 psf
Operating Expenses	$8,000	$8 per sf
Expense Growth Rate		2.00% /yr
Leasing Commissions		$3.25 psf
Equity Requirement -	35%	$ 5,838,000
Capital Reserve		$1.25 psf
Total Cost	16,680,000	$278.00 psf

Construction Loan	
Amortization	0 Years
I/O Period	5 Years
Constr. Loan Int Rate	4.75%
Constr. Loan Fee	1.00%
Payoff Date	Month 26
Proceeds	$ 10,842,000

Exit	
Sale Month	Month 144
Terminal Cap Rate	7.00%
Exit NOI	2,137,297
Sale Price	30,532,821
Cost of Sale	2.00%
Sale Proceeds	29,922,164

Refinance	
Loan to Value	70%
Amortization	20 Years
Loan Proceeds	17,033,712
Interest Rate	4.5%
Commencement	Month 26
Payoff Date	Month 144
Fee	1.0%
Cap Rate	6.50%
Valuation	$ 24,333,874

Investment Returns	
Levered IRR	29.49%
Levered NPV	10,197,855
Unlevered IRR	12.82%
Unlevered NPV	$6,363,758
Levered Discount Rate	8.00%
Unlevered Discount Rate	8.00%

Table 2 - Financial baseline scenario assumptions

This baseline scenario is reflective of the standard underwriting model a developer would produce during the analysis stage of a new real estate development. Given the assumptions above, the IRR on a levered and unlevered basis are 29.49% and 12.82% respectively.

Financial Analysis Scenarios:

Scenario 1 – Normative DSM:

This scenario is based on the normative DSM created and introduced on Figure 18 on pg. 57. The unplanned iterations (failure modes) in this DSM had a cost and time assigned to them. Through our interviews we were able to identify and measure the impact unplanned iterations have on to the RED for each of the unplanned iteration stages we defined earlier (Determining Modularity through Design, Project Definition, Rework Design, Project Delays). Based on our conversations with the GC and lead architect for 30 Haven and their estimates for the approximate time and cost of delays in each stage, we generated the data in Table 3. We then estimated the probabilities of each event occurring.

	Normative DSM				
Unplanned Iteration Stage	**Likelihood of Impact**	**Average Rework Duration**	**Average Rework Cost**	**Total Time Delay (Days)**	**Total Cost**
Determining Modularity Through Design	20%	21 Days	$25,000	4 Days	$5,000
Project Definition	30%	63 Days	$100,000	19 Days	$30,000
Rework Design	20%	14 Days	$15,000	3 Days	$3,000
Project Delays					
Parallel Construction/Site Issues	80%	196 Days	$300,000	157 Days	$240,000
MEP Integration & Construction Completion	30%	14 Days	$20,000	4 Days	$6,000
Total Potential Impact		**308 Days**	**$460,000**	**187 Days**	**$284,000**

Table 3 - Normative DSM unplanned iteration effects summary

We then multiply the probability of occurrence by the average time delay and the average cost to arrive at the values highlighted in grey to overlay on the baseline analysis.

(Likelihood of Impact x Average Rework Duration) = Total Time Delay (Days)

(Likelihood of Impact x Average Rework Cost) = Total Cost

By layering these timing and cost results into the model we generate a project IRR and NPV for the unplanned iterations that affect the normative DSM (Table 3). We provide a comparative analysis to the baseline financial pro forma on a timing only effect, a cost only effect and a combined effect. The timing only comparison looks at the effect on return of the time delay only. The cost only comparison looks at the effect on return for the additional costs only (without the added time) and provides a return based on whether the additional costs are funded through additional equity or additional debt. Finally, the combined time and cost effect takes both into account. The results of this analysis are as follows Table 4:

			Cost Only		Combined (Timing & Cost)	
		Timing Only	Equity	Debt	Equity	Debt
	DCF - Baseline	DCF - Normative DSM	DCF - Normative DSM	DCF - Normative DSM	DCF - Normative DSM	DCF - Normative DSM
Levered IRR	29.49%	26.90%	28.14%	28.56%	25.78%	26.15%
Levered NPV	$ 10,197,855	$ 9,998,086	$ 9,926,761	$ 9,957,580	$ 9,726,993	$ 9,763,723
Unlevered IRR	12.82%	12.53%	12.58%	12.58%	12.29%	12.29%
Unlevered NPV	$ 6,363,758	$ 6,066,855	$ 6,092,665	$ 6,092,665	$ 5,795,761	$ 5,795,761
Construction Loan	$ 10,842,000	$ 10,842,000	$ 10,842,000	$ 11,126,000	$ 10,842,000	$ 11,126,000

Table 4 - Normative DSM financial analysis summary

As we can see in the table above, timing is the strongest driver to the normative DSM model's reduced return. The baseline levered IRR is 29.49%, while the levered IRR for the *time only delay is* 26.90%. This is a reduction of 2.59%. The levered IRR for the *cost only effect* is 28.14% and 28.56% when funded through equity or debt, respectively. This is a 1.35% and a 0.93% reduction in IRR, respectively**. The levered IRR for the *combined time and cost effect* is 25.78% and 26.15% when funded through equity or debt, respectively. This is a reduction from the baseline scenario of 3.71% and 3.34%, respectively**. As expected, the NPV is reduced for each scenario as well and the results can be seen in Table 4 above. Please note that we only provide details on the levered IRR, since the unlevered IRR has a very minimal impact between scenarios and an unlevered project is financed entirely through equity. The additional costs on an unlevered basis are also unchanged whether it is paid for through debt or equity because, again, by definition, an unlevered return does not take into account any debt, therefore the additional cost is financed by the equity partner.

The changes can be viewed in a summary format in Table 5 below.

Scenario 2 – Optimal DSM:

In this scenario we simply take into account the elimination and minimization of the likelihood and impact for the unplanned iterations in each stage of the normative DSM to reflect the optimized DSM. . Table 5 below compares the normative DSM's likelihood of impact, the average rework duration and the average rework cost. **The table shows the reduction in all cost and delays for the optimal DSM scenario, showing how the minimization and elimination of the unplanned iterations produce cost and time savings.**

	Normative Modular DSM					Optimal Modular DSM			Change (Optimal vs. Normative)		
Unplanned Iteration Stage	Likelihood of Impact	Average Rework Duration	Average Rework Cost	Total Time Delay (Days)	Total Cost	Likelihood of Impact	Total Time Delay	Total Cost	Likelihood of Impact	Total Time Delay	Total Cost
Determining Modularity Through Design	20%	21 Days	$25,000	4 Days	$5,000	5%	1 Days	$1,250	-15%	-3 Days	($3,750)
Project Definition	30%	63 Days	$100,000	19 Days	$30,000	15%	9 Days	$15,000	-15%	-9 Days	($15,000)
Rework Design	20%	14 Days	$15,000	3 Days	$3,000	0%	0 Days	$0	-20%	-3 Days	($3,000)
Project Delays											
Parallel Construction/Site Issues	80%	196 Days	$300,000	157 Days	$240,000	50%	98 Days	$150,000	-30%	-59 Days	($90,000)
MEP Integration & Construction Completion	30%	14 Days	$20,000	4 Days	$6,000	15%	2 Days	$3,000	-15%	-2 Days	($3,000)
Total Potential Impact		**308 Days**	**$460,000**	**187 Days**	**$284,000**		**111 Days**	**$169,250**	**0%**	**-76 Days**	**($114,750)**

Table 5 - Optimal DSM unplanned iteration effects summary

The reduced probability for the optimal DSM thanks to the minimization of the unplanned iterations and their likelihood results in a reduced time delay of 76 days or 2.5 months. The cost impact has been reduced by a total of $114,750 (from $284,000 to$169,250). These changes result in an increased IRR for the optimal DSM scenario when compared to the normative DSM scenario. The results can be seen below in Table 6:

			Cost Only		Combined	
		Timing Only	Equity	Debt	Equity	Debt
	DCF - Baseline	DCF - Optimized DSM	DCF - Optimized DSM	DCF - Optimized DSM	DCF - Optimized DSM	DCF - Optimized DSM
Levered IRR	29.49%	27.53%	28.67%	28.93%	26.82%	27.05%
Levered NPV	$ 10,197,855	$ 10,024,976	$ 10,036,296	$ 10,054,566	$ 9,863,418	$ 9,884,382
Unlevered IRR	12.82%	12.59%	12.68%	12.68%	12.45%	12.45%
Unlevered NPV	$ 6,363,758	$ 6,126,572	$ 6,202,200	$ 6,202,200	$ 5,965,014	$ 5,965,014
Construction Loan	$ 10,842,000	$ 10,842,000	$ 10,842,000	$ 11,011,250	$ 10,842,000	$ 11,011,250

Table 6 - Optimal DSM financial analysis summary

As we can see in the table above, timing has a greater effect on the returns than do the additional rework costs. The baseline levered IRR is 29.49%, while the *time only delay* impact has a levered IRR of 27.53%. This is a reduction of 1.96%. The *cost only effect* on the levered IRR is 28.67% and 28.93% when funded through equity or debt, respectively. This is a 0.82% and a 0.56% reduction in IRR, respectively. The levered IRR effect on a combined *timing and cost basis* is 26.82% and 27.05% or 2.67% and 2.44% when financed through equity or debt, respectively.

The set of tables (Table 7) below shows the resulting scenarios as discussed earlier in comparison to the baseline scenario.

		Timing Only			
	DCF - Baseline	DCF - Normative DSM	Diff	DCF - Optimized DSM	Diff
Levered IRR	29.49%	26.90%	-2.59%	27.53%	-1.96%
Levered NPV	$ 10,197,855	$ 9,998,086	$ (199,769)	$ 10,024,976	$ (172,879)
Unlevered IRR	12.82%	12.53%	-0.29%	12.59%	-0.23%
Unlevered NPV	$ 6,363,758	$ 6,066,855	$ (296,904)	$ 6,126,572	$ (237,187)
Construction Loan	$ 10,842,000	$ 10,842,000	$ -	$ 10,842,000	$ -

		Cost Only - Equity				Cost Only - Debt			
	DCF - Baseline	DCF - Normative DSM	Diff	DCF - Optimized DSM	Diff	DCF - Normative DSM	Diff	DCF - Optimized DSM	Diff
Levered IRR	29.49%	28.14%	-1.34%	28.67%	-0.81%	28.56%	-0.93%	28.93%	-0.56%
Levered NPV	$ 10,197,855	$ 9,926,761	$ (271,093)	$ 10,036,296	$ (161,558)	$ 9,957,580	$ (240,275)	$ 10,054,566	$ (143,288)
Unlevered IRR	12.82%	12.58%	-0.24%	12.68%	-0.14%	12.58%	-0.24%	12.68%	-0.14%
Unlevered NPV	$ 6,363,758	$ 6,092,665	$ (271,093)	$ 6,202,200	$ (161,558)	$ 6,092,665	$ (271,093)	$ 6,202,200	$ (161,558)
Construction Loan	$ 10,842,000	$ 10,842,000	$ -	$ 10,842,000	$ -	$ 11,126,000	$ 284,000	$ 11,011,250	$ 169,250

		Combined - Equity				Combined - Debt			
	DCF - Baseline	DCF - Normative DSM	Diff	DCF - Optimized DSM	Diff	DCF - Normative DSM	Diff	DCF - Optimized DSM	Diff
Levered IRR	29.49%	25.78%	-3.71%	26.82%	-2.67%	26.15%	-3.34%	27.05%	-2.44%
Levered NPV	$ 10,197,855	$ 9,726,993	$ (470,862)	$ 9,863,418	$ (334,437)	$ 9,763,723	$ (434,131)	$ 9,884,382	$ (313,472)
Unlevered IRR	12.82%	12.29%	-0.53%	12.45%	-0.37%	12.29%	-0.53%	12.45%	-0.37%
Unlevered NPV	$ 6,363,758	$ 5,795,761	$ (567,997)	$ 5,965,014	$ (398,745)	$ 5,795,761	$ (567,997)	$ 5,965,014	$ (398,745)
Construction Loan	$ 10,842,000	$ 10,842,000	$ -	$ 10,842,000	$ -	$ 11,126,000	$ 284,000	$ 11,011,250	$ 169,250

Table 7 - Resulting scenario comparative analysis between normative, optimal and baseline scenarios

As expected and explained above the more efficient process produced for the optimal DSM (Figure 19) through the elimination of unplanned iterations and the reduction in impact and the likelihood of unexpected events lessens the negative impact that is usually associated with any ex post IRR and NPV for typical RED projects. The IRR on a combined timing and cost basis is increased by 1.04% (-3.71% - -2.67%) on an unlevered basis and 0.90% (-3.34% - -2.44%) on a levered basis from the normative DSM model (Figure 18). While timing has the largest impact on the reduced return, the combined timing and cost effect has the most dramatic effect, but the impacts are minimized for the optimal model.

Conclusions

While the resulting impacts of time and rework costs on the returns are not overly high (the maximum difference in IRR's came from the difference in returns between the normative model and baseline model's equity-based combine cost and time returns, a 3.71% IRR difference), the financial analysis shows that there is still a significant financial benefit to optimizing the process through the elimination or reduction of unplanned iterations. It is also important to note that time (i.e. delays) was identified as a very strong effect, and should be monetized by developers in order to be able to foresee their effect.

The optimization of an RED process can have a lower impact on returns in a stable or strong market because of a potentially greater profit margin, but aiming for an optimal RED process using MCM is still recommended. Optimization in any market setting can have a very big impact on returns and may result in a project remaining profitable in a down market. Optimizing the process and minimizing iterations is one important element of the development process. However, optimizing the process does not eliminate the need for the developer to focus on the core components of the development process. The developer needs to properly research and a understand the market, build the highest and best use project, and structure the financing in such a way to drive the greatest return for the equity partners.

Chapter 10: Conclusions and Recommendations

Chapter Introduction:

We began our research on modular construction expecting to understand the limitations and benefits of MCM and how it fits into a normative RED process. We were able to not only understand the negatives and positives of an MCM process and its role in a RED, we were also able to deepen our understanding of the planning required to effectively carry out tasks and to avoid the potential pitfalls that a developer faces along the way. In this chapter we summarize our findings and conclusions based on the research and analysis we conducted, via the DSM and through a hypothetical financial model.

We also recommend additional new DSM applications related to RED and a number of specific routes future researchers and interested parties could take. Future studies could focus on the advantage MCM poses for RED or could emphasize the future applications of MCM, a construction method which holds promise for developers looking to achieve shorter durations for projects using different materials and structures (e.g. the steel and concrete traditionally used to build skyscrapers). The Chinese have recently been in the news for accomplishing amazing building feats using MCM, amongst the most noticeable buildings was a thirty story hotel built in just fifteen days (MacKenzie, 2012). As the world experiments with broader commercial applications of MCM, more opportunities become accessible for future studies and applications.

We end the chapter, and this thesis, with mention of recent academic research on digital design, systematic planning and systems-based thinking. RED's begin, in essence, as just ideas – they are turned into reality through proper execution. If the idea's design, whether it is for a product, or a real estate development, is sound, and the execution of that idea is effective, then the system or process will function effectively.

Summary of Findings and Conclusions

Our findings point towards specific preemptive actions a developer could take to derive the maximum benefit from using MCM.

According to our findings, a developer will profit most from an RED using MCM when they adhere to the following:

Defining the project's design early on, accomplished by first abiding to the requirements in a modular design, followed by producing a conceptual design that allows for changes but will not pose considerable rework down the line.

Integration between the developer and any external party is key: as with any development, the developer will have to work simultaneously with the different architects, engineers, financiers, government officials and public representatives involved. However, with MCM, there is a tighter schedule which limits the amount of time that can be wasted. RED projects using MCM require developers to properly integrate with all the parties involved in the RED sooner than in traditional site built projects, promoting integration early on to help the different entities plan together for the activities they will be taking on together.

Well-coordinated parallel tracks and properly coordinated activities provide the best results during the manufacturing/construction stage. The developer's integration efforts, specifically those concerning the modular manufacturer, will be put to the test once the development reaches the stage where the work onsite and in the modular manufacturing facility is going on at the same time.

Developers should always be concerned about the "learning curve effect" that occurs once the modules are set on site. MEP and other specialty systems are connected on site when the modules are first set. Connecting the modules and the systems between them is achieved through the combined efforts of the subcontractors, who are supported by the manufacturer's site setting crew and guided by the GC. The whole process is not entirely intuitive to subcontractors, who have most likely not dealt with many MCM-based RED projects before. If developers watch out for this, they will be able to foresee whether the systems that will be connected on site require a complex installation, and if so, can avoid a steep learning curve by having subcontractors involved with the module manufacturing process beforehand.

IPD (Integrated Project Delivery) methods provide a solution to properly "balance" and provide efficiency for the whole RED process. The alignment of incentives and collaboration that more easily occurs with IPD methods fit in nicely with the high level of teamwork that MCM projects require. Value increases when less money and time is wasted because the developer, GC, architects and designers are all working to complete the project on time and on budget, instead of simply "providing a service".

Practical lessons and recommendations derived from the application of the DSM

While the application of the DSM to RED, has until now, been applied only in an academic and theoretical setting, there are still opportunities to make use of this tool in a professional setting. We are, however, aware that both (i) the professional real estate development world might be apprehensive in using an academic tool and that (ii) initially, the DSM, although simple enough to understand, might appear complex. The DSM will always require users to go through a slight learning curve, but in reality, most new users are able to understand DSM modeling very quickly. It is also true that many sophisticated real estate developers and those with enough RED experience already follow the correct "critical path" in their projects. These developers instinctively make sure to plan the correct iterations and avoid the unplanned ones through their practice, know-how and intuition.

Nevertheless, there are important lessons that we derived from applying an activity-based DSM to the RED process using MCM which we can summarize in a practical manner as the following:

List out and prioritize activities, making sure to know what each activity depends on and what each activity provides. Developers are expected to be cognizant of their role in a RED process, which involves leadership skills, demonstrated through coordinating teamwork efforts and delegating tasks competently. Prioritizing these activities, and being aware of what information each of them depends on and what information each of them provides will help make the developer more responsive to changes in the process as they arise. Developing this "sensitivity" can help a developer manage processes smoothly.

Assign red flags and warnings to possible unexpected situations, acknowledging their possible occurrence and what consequences they will put forth. The ultimate solution in dealing with the unexpected is preparedness and effective planning. The best way to accomplish this is to identify the problems that can occur, especially those that are unforeseen. By changing the unexpected into the expected, the developer can be one step ahead of the game.

Look to solve unexpected situations by either minimizing or eliminating the likelihood of them occurring and dealing with those that do occur by decreasing their impact. The financial model we produced was meant to consider the burden of theoretical rework costs and time delays if the project were to encounter unplanned iterations. By minimizing the probability of unexpected events occurring and softening their impact it became possible to derive savings on both the costs and time delays. A developer can be mindful of these potential savings, and can be more motivated in planning for unforeseen circumstances if they quantify their savings.

Other Future DSM Applications

We were able to use the DSM to our advantage, as a systems modeling technique with which we were able to visualize the process in a general level, analyze interactions between activities at a detailed level and work out solutions to either minimize or eliminate the possibility of unexpected events occurring in the process.

Opportunities exist for future DSM applications of the RED process that uses MCM. Our application of the DSM was process-based, and thereby focused on activities. The following describes the different DSM architecture applications that could be applied:

Product DSM – Product-based DSM's focus on a product's architecture, by fragmenting a complete product or system into separate clusters or sections, to better view the sub-systems that make up the larger, complete system. This application can be used to describe the MCM process, where modules can be considered products and where the manufacturing of them can be considered a product-based system. Previous applications of the product-based DSM to manufacturing has been applied successfully to jet engines, printing technology, NASA technology, browser software and has even had fruitful applications to the construction of specialized schools in the UK (Eppinger & Browning, 2012). An MCM process would be analyzed closely, looking at its subsystems and potential inefficiencies, so as to apply the correct manufacturing optimization process restructuring where needed. An RED process using MCM would clearly benefit through an optimized modular manufacturing process.

Organizational DSM – Organization-based DSM's focus on the organizational architecture that is integral in carrying out any process. Organizational DSM's can take on three "mappings": (i) hierarchical decomposition, (ii) work assignments and top down reporting relationships and (iii) lateral relationships (interaction work). In essence, the communication between the different members of an organization can be mapped out, to measure their natural clustering when it comes to the process's activities, the organizational overlap in responsibilities, the frequency in interactions between elements and the proper allocation of skilled labor in the process (Eppinger & Browning, 2012). In an RED process that uses MCM, organizational functions can be mapped out via an organizational DSM to measure the managerial and operational clusters that exist in the process, to analyze their interactions and figure out if they conform ideally to the needs of the process (i.e. fueling integration efforts between the developer and external parties, properly coordinating the parallel tracks that go on between the manufacturing and construction).

Multidomain and Domain Mapping Matrix (DMM) DSMs: Multidomain DSM's combines single-domain DSM's and displays two or more of them concurrently. Domain Mapping Matrices (DMMs) can map combinations of two domains, such as interactions between any pair of the following: product components, organizational units and process activities. Multidomain Matrices (MDMs) can go beyond paired combinations and achieve a larger range of comparison, where more than two DSM domains can be compared at once (Eppinger & Browning, 2012). RED projects using MCM can derive misalignment between organizational functions and the manufacturing of the modules, exposing whether the different people involved in the process are truly "integrating" with each other or not. The same multidimensional concept analysis can be applied to uncover the true nature of the parallel work that goes on between the developer, GC and manufacturer when the modules first arrive on site, when they're set and when the MEP systems are connected.

Research on the effect of proper design, systematic planning and its importance

The current widespread digitalization of modern systems has had a positive effect on product design and the systematic planning for its execution. Marion, Fixson and Meyer's Sloan Management of Review article "The Problem with Digital Design" argues that modern digital design has produced superlative tools, completely capable of achieving superior design quality and execution, but that these tools fall short of serving their purpose if they are mismanaged (Marion, Fixson, & Meyer, 2012). The same can be said for any mismanagement of advanced planning and design tools like Enterprise Resource Planning (ERP) and Building Information Modeling (BIM) software systems, tools that are now employed in modern RED.

Proper focus on optimal management practices has managers constantly working to avoid GIGO (Garbage In, Garbage Out), meaning that they continuously supervise the quality of process inputs in order to produce favorable outputs. Marion, Fixson & Meyer demonstrated through their research that process monitoring, having minimal (or zero) changes occur late into the process and allocating considerable resources into the early stages of a process reduces iterations and ensures better results (Marion, Fixson, & Meyer, 2012).

The aforementioned authors' research results and the design and execution-based efficiencies derived therefrom can be directly applied to RED projects using MCM, and can also corroborate the findings and conclusions we derived from applying the DSM to an RED process using MCM. Our analysis placed a comparably strong emphasis on the same disciplined activities Marion, Fixson & Meyer found to be important to successful design and production processes: monitoring, intelligent iteration management and developer/external party integration efforts in the initial stages.

While it is possible for any real estate developer to simply build, only those that use the proper tools and management principles to design and execute a real estate development process come closer to achieving a truly successful development.

Glossary 1 - Traditional Site Built and Modular Development DSM

Acquire Property - [Preconstruction] – In a normative model this would occur once the approvals are in place, but in reality a developer may acquire a property prior to obtaining the proper zoning and variance approvals.

Back of the Envelop Proformas - [Idea Inception] **–** With some of the market information determined, the developer will conduct various types of "back of the envelope" calculations. This will involve incorporating all the market information and comparative data for rentals and costs into the model. This quick, unscientific calculation will help determine a high level feasibility test.

Build Core and Shell - [Construction] – This includes building of the structure and exterior of the building. This usually includes life safety systems. Some work to facilitate tenant improvement work may be included as well.

Begin Manufacturing of Modules - [Factory] – This is the date the manufacturer begins production of the modules for the project. This date is determined by understanding the production capacity of the factory and knowing the set date of the first module.

Build Non-Modular Commercial and Common Space – [Site Preparation] – The on-site construction needs to be completed prior to the modules arriving on site. This includes having the foundation ready and any steel structure/common space prepared. There needs to be space for the crane and a loading area for the transport trucks.

Build Project Infrastructure On-Site – [Site Preparation] – The foundation, drainage, utility connections, etc. all need to be installed prior to the modules arriving on site.

Build Project Infrastructure - [Construction] – This includes any work, outside of the building(s) itself, that may need to be built before full construction begins. In the case of modular it entails getting the site grading and excavation complete, foundation poured, utilities connected, and any steel erected so the modules can be set.

Build Tenant Improvements - [Site Work & Complete Construction Work] – This includes all interior construction. When and what is built will depend many factors, including the product, the market, leasing progress and specific tenants.

Building Turnover - [Site Work & Complete Construction Work] – After substantial completion, the developer and/or the tenants will take control of the space from the contractor.

Clear Title Report - [Preconstruction] – The developer will need to ensure that the title on the property is free and clear from any encumbrances.

Complete Phase 1ESA - Environmental Site Assessment (ESA) - [Feasibility] – Environmental conditions pose a significant risk the profitability of a development, especially on redevelopment sites. An initial analysis is conducted at this stage to identify these risks. This is a due diligence stage, and physical sampling is not usually collected at this stage.

Collect Rents - [Stabilization] – Tenants will start paying rent (or purchase part of the property) once they move in.

Complete Phase 2 ESA - [Preconstruction] - With the site under control, the developer will want to engage an environmental consultant to complete a Phase 2 ESA. This will determine whether or not the site is contaminated and if necessary, remediation requirements.

Construction Loan Administration - [Site Work & Complete Construction Work] – The bank will need to inspect the project and ensure it is being properly constructed. This is usually done on a monthly basis, to ensure the monthly draws are correct and the project is adequately funded throughout construction.

Construction Inspection - [Site Work & Complete Construction Work] - Throughout the construction project, the developer will need to ensure that construction complies with the contract documents.

Contractor Estimating - [Preconstruction] – As the design becomes further established, the developer will want to maintain some level of check against the original budget. The design stage may take a significant amount of time, and updates to the budget are necessary to ensure no drastic changes occur late in the process.

Design Development - [Preconstruction] - The design is further refined after schematic design. The level of design between this stage and the previous will depend on the developer's preference, the demands of the approval agencies, etc.

Design Integration between Developer & Manufacturer – [Preconstruction] – Choose the lead designer and the CAD tech that will work on the entire project from start to finish. There will be communication between the architect and the engineer to go from architectural design, to BBRS approved drawings to shop drawings for the manufacturing of the modules. This can be improved by using a BIM software so all changes are made immediately to all the drawings rather than transferring information from the architect's drawings to the CAD drawings (which need to be updated manually) at the manufacturer.

Determine Exit Strategy - [Preconstruction] - The developer will want to establish an exit strategy and ensure they comply with the debt and equity agreements, along with the expected market conditions.

Determine Highest and Best Use - [Feasibility] – This task allows the developer to determine the best product for a specific site. From this point on, the highest and best use will be further refined to a final product.

Determine Set Date - [Preconstruction] – The set date is the driving factor behind the entire project schedule. Once the set date is determined, the project schedule can be backed into and is key to determining when the site work needs to begin to be ready for the modules. Understanding the manufacturer's capacity is important in determining the set date so that the modules are on site and ready to be installed. In many cases this date is determined far in advance and both the GC and manufacturer can back into their respective schedules.

Develop Conceptual Design - [Feasibility] – With a massing study complete, one or multiple conceptual designs need to be completed to get an idea of a possible product. If approved, this design will be further developed later in the process.

Develop Marketing Strategy - [Preconstruction] - A full marketing plan is developed to determine how the property will be leased and or sold. The market analysis will determine much of this strategy.

Develop Project Schedule - [Preconstruction] - After most of the preconstruction tasks are complete, a project schedule can now be finalized.

Develop Project Schedule and Deadlines between Developer/Manufacturer - [Preconstruction] – The timeline is determined by the developer and manufacturer. Each need to work their schedules based on the set date. The manufacturer needs to determine the production schedule, while the GC and developer need to determine when to begin site work and when to start scheduling the subcontractors that will finish the building once the modules are set.

Engage Feasibility Consultants - [Feasibility] - Here the developer evaluates and engages in consultants necessary to complete tasks within the feasibility stage. This will include design consultants, contractors and legal counsel.

Engage Full Consulting Team - [Preconstruction] – All consultants will need to be signed up to get through the *Preconstruction* stage. This includes lawyers, designers, preconstruction contractors, etc.

Estimate Costs - [Idea Inception] - Development costs, including both soft and hard costs, will need to be estimated to compare with the estimated rents. These numbers will be rough as the timing and design of the project have not yet been determined. The balance between the two will ultimately determine whether or not the project is achievable.

***Estimate Project Scope - [Idea Inception]* –** This is a broad attempt to determine the size of the project. This is on the magnitude of number of buildings, height, floors, square footage, and the costs associated with the building. This is based on information gathered from other tasks in the *Idea Inception* stage.

Estimate Project Timeline - [Idea Inception] – The developer will need to evaluate the timeline of development for the possible projects and compare that with the organization's strategy.

Estimate Rents - [Idea Inception] - By looking at comparable projects and market conditions, the developer will seek to understand what type of rents the project will be able to achieve. This will ultimately be used to calculate the initial financial assumptions. These rents will be rough estimates, as the final timing, product mix and design of the project is unknown.

Estimate Schedule - [Feasibility] - Throughout this stage, the developer will want to continuously evaluate the project's schedule.

Evaluate Capital Markets - [Asset Management and/or Sale] - The capital markets will determine if and how the property can be refinanced and/or sold once it becomes a stabilized asset.

Evaluate Capital Markets - [Idea Inception] - An understanding of the capital markets is conducted to understand the cost of capital and the level of risk that the market will tolerate.

Evaluate Consultants and Contractors - [Feasibility] - As the idea becomes more of a reality, the developer will start evaluating and meeting with potential consultants and contractors for the preconstruction and construction phases. These consultants may or may not be the same as those completing some of the feasibility tasks.

Evaluate Investment Thresholds - [Idea Inception] – The developer will need to determine the investment thresholds and risk tolerances of the organization.

Evaluate Land Control Options - [Idea Inception] – Each site will require different steps for the developer to gain control. The developer will need to evaluate each of them and determine the risks and return for each.

Evaluate Local Politics - [Idea Inception] - An understanding of the political acceptance of development is required to understand what is to be expected. Some projects are encouraged by the public, while others can face years of opposition. This will affect the costs and timeline of the project.

Evaluate Marketability Options - [Feasibility] - This task evaluates how the specific project would be introduced into the marketplace. How long would absorption take, how the market will respond to the product, etc.?

Evaluate Organization Strategy - [Idea Inception] - During the idea phase, the developer will need to determine the organization's strategy. They may have types of projects they specialize in (size, program, etc.) as well as the level of risk they are willing to take on.

Evaluate Organization Strategy - [Asset Management and/or Sale] - Different companies will have different strategies on whether to hold or sell an asset. This may depend on the value of the property, other development opportunities, etc.

Evaluate Planning and Zoning Process - [Feasibility] - Here the entitlement process is fully understood to determine potential risks, costs and timing. Much of the design will be completed in stages based on this process.

Evaluate Programmatic Options - [Idea Inception] - Here different uses are evaluated to determine the possibilities. These would include residential (for sale or lease), commercial, hotel, industrial, mixed use, etc. There may be multiple options still feasible after this task has been completed.

Evaluate Project to Determine Modularity - [Idea Inception] – The project needs to be assessed to determine if the site can accommodate modular boxes arriving on site, the mix of uses (retail doesn't work), the desired timeframe for completion, and the local labor market – can the developer capture an arbitrage opportunity for the labor required, can the developer partner with a contractor that can handle modular, can financing be obtained from a bank for modular, can the design accommodate modular building?

Evaluate TI Requirements - [Preconstruction] - The cost and complexity of tenant requirements will need to be determined in this stage. The developer will need to determine what is being built under the classification of base building, and what is being built as part of tenant fit up.

Evaluate Zoning/Planning - [Idea Inception] – Evaluation of how the entitlement process generally works, as of right restrictions and likelihood of changes or variances to the current zoning requirements.

Execute Construction Agreement - [Site Preparation & Module Set] – The developer needs to execute an agreement with a general contractor to complete the work on site to prepare the site for the modules and to finish the work once all the modules have been set.

Execute GC and Fee Agreement - [Preconstruction] – The developer will most likely want to first execute a general conditions (GC) and fee agreement with a contractor. This will lock in the overhead costs of construction and allow the contractor to act in a fiduciary manor with the developer during preconstruction and value engineering activities. While this is a popular delivery method, many other factors will go into determining how the developer will proceed.

Execute GMP Agreement - [Construction] - With a final design and an approval to start construction, the developer will most likely choose to lock in a guaranteed maximum price with a contractor.

Financial Underwriting – 1st Draft - [Idea Inception] - With the tasks above completed, the developer can complete an initial underwriting of the project. Based on our discussions, a majority of the projects evaluated do not pass this initial test.

Finalize Development Budget - [Preconstruction] – With near complete construction documents and a significant amount of soft costs spent, the development budget will need to be updated for the bank, equity partners and the developer to ensure project feasibility.

Gain Control of Site and/or Client - [Feasibility] - Near the end of the *Feasibility* stage, the developer will be faced with a decision of whether or not to proceed with preconstruction. Before starting with preconstruction, which requires a significant amount of soft cost expenses, the developer will want to ensure that the site is under control.

Identify Land Opportunities - [Idea Inception] – Potential project sites are determined and evaluated at this point.

Identify External Stakeholders - [Feasibility] - The stakeholders need to be determined to understand who will play a role in the development of the project. This will include neighbors, the public, politicians, competitors, etc.

Identify Modular-Specific Permits and Approvals - [Feasibility] – These approvals will determine the work that is required to be completed, the timing of the construction and the manufacturing schedule of the modular components. Examples include BBRS, Third Party Quality Control, Transportation Permits, etc.

Integrate Manufacturer in Design Process - [Feasibility] – Formally integrating the manufacturer into the design process from the beginning. This helps reduce iterations related to the building design and ensure the architects design a product that can be built efficiently in a modular setting.

Identify Permits and Approvals - [Feasibility] - These approvals will determine a lot of the work that is required to be completed in the second and third stages of development. They will play an important role in the design, cost and timing of development.

Identify Debt Options - [Feasibility] - With a general understanding of a product, schedule and budget, the developer can begin to evaluate what the options are for debt financing, including certain terms, loan to value ratios, etc.

Identify Equity Options - [Feasibility] - The developer will need to identify where the remaining funds will come from. The funds will most likely be required during the preconstruction phase before any money from the construction loan can be used.

Initial Contractor Discussions - [Preconstruction] - During preconstruction, the developer will want to work towards securing a contractor to build the project. This will first require a lengthy de-scope process to minimize the amount of uncertainty. The developer may prefer to sign a contractor early to take advantage of preconstruction services and a fiduciary construction partner.

Implement Property Management - [Stabilization] – The property manager will need to start operating the building as the construction team begins to leave. There will most likely be an overlap as all issues are resolved.

Leasing Process/Prelease - [Preconstruction] - During preconstruction, the leasing process can begin. This includes looking for an anchor tenant, along with other tenants. Some banks (market depending) will want to see formal commitments before committing to a project.

Local Supply and Demand Analysis - [Idea Inception] – Local market conditions will play a significant role in how a development is developed if at all. It will show projects that are in the pipeline, expected absorption rates and the demand for new space.

Macroeconomic Analysis - [Idea Inception] – This task includes evaluating national macroeconomic indicators, such as unemployment rates, demographic changes, and interest rates. Certain factors may indicate a demand in the marketplace.

Manufacturer Involvement in Contractor Estimation - [Preconstruction] – The manufacturer needs to integrate the sub-contractor into the design and bidding process. The subcontractor is ultimately responsible for making all the final connections and the final inspection by the local building inspector, therefore the subcontractor needs to be involved in the design and potentially fabrication of their particular subcomponent (i.e. sprinklers). This is also where the mock up units are assembled and reviewed by the subcontractors so the subs can more accurately quote the work they will complete on site.

Market and Economic Feasibility Analysis - [Idea Inception] – This task includes evaluating national macroeconomic indicators and the local market dynamics. Items to look at include unemployment rates, demographic changes, absorption figures, rental comparisons, and interest rates. Certain factors may indicate a demand in the marketplace.

MEP System Integration Work – The mechanical, electrical and plumbing systems need to be connected across each module and for the entire building. In many cases the coordination with these subcontractors will be done early or the sub may even go to the factory to install the systems. This is done to ensure the connections on site go as smoothly as possible.

Module Storage & Inventory [Factory] – Once the modules are completed in the factory they need to be stored and held in inventory until the site is ready to receive the boxes and set them in place. Ideally, the boxes will be stored on site at the factory so they are held in a secure location and can be easily repaired if any damage, weather or otherwise occurs.

Monitor Schedule [Site Work & Complete Construction Work] – The schedule needs to be monitored and adjusted as the final work on site is completed. This helps in providing additional information to the underwriting and on-going property management functions of the building, including the tenant move-in date.

Monitor Schedule - [Construction] - The schedule will need to be continuously updated throughout construction as tasks are completed. The duration of the project will affect borrowing costs, future rents and tenant activity.

Move Tenants In - [Stabilization] - The moving in of tenants signifies substantial completion of construction and the beginning of cash flows.

***Negotiate Debt Agreements - [Preconstruction*]** - There is very little difference to regular financing for site built projects. The issues that arise are due to the fact that some banks are not comfortable with lending on modular units because the asset is technically nonexistent and not part of the real property until it is completely set. Payment terms with the manufacturer will vary, but generally banks do not release funds until the modular units are on site and installed. In some cases banks will release funds to pay the manufacturer as the units are produced if they have a Right to Seizure Clause (allows the bank to come on site at any point and take the product) and units are insured and bonded.

Obtain BBRS Approved Drawings - [Preconstruction] – The BBRS (The Board of Building Regulations and Standards) is a state agency in Massachusetts that approves all building systems and designs. Once the BBRS approves and stamps the construction documents, the building can be assembled in the factory.

Obtain Building Permit - [Construction] - A building permit will need to be obtained prior to any construction activities commencing.

Obtain Modular Building Permits - [Factory] - The modular drawings are 100% complete prior to the start of manufacturing. Therefore, the complete set of building permits can be applied for once. This saves time and money from the typical process of applying for specific permits as needed for a regular site built project. A fast track situation would be the only reason the permits may be applied for separately. Depending on the level of risk the developer decides to incur will determine when in the development process the permits are obtained.

Obtain Certificate of Occupancy - [Stabilization] - Once the building is mostly complete and all life safety systems are online, the authorities will grant a certificate of occupancy. This may occur at the time of temporary certificate of occupancy if the construction is far enough along.

Obtain Planning and Zoning Approvals - [Preconstruction] - All necessary planning and zoning approvals will be obtained during this stage.

Obtain Miscellaneous Permits and Approvals - [Preconstruction] – All other necessary permits and approvals will be secured in this stage.

Obtain Rough Construction Costs - [Feasibility] - With massing and conceptual designs complete, the developer is able to get initial estimates on the product. While still budgetary, it will help the developer identify significant issues that may require rework.

Obtain Temporary Certificate of Occupancy - [Construction] - Once the building is substantially complete and all life safety systems are online, the local authorities will grant a certificate of occupancy. This may only be temporary if there is a substantial amount of construction activities still left to be completed.

On-Site Construction Completion Coordination with Modular Transport - [Factory] – The factory needs to be in constant communication with the on-site crew to determine if the production levels need to be ramped up or down and then to ensure the transportation of the modules are arranged so the modules arrive when they are ready to be set.

Perform Formal Market Analysis - [Preconstruction] - A formal market study is conducted to completely evaluate all market conditions. The size and cost of the market study will vary depending on the size of the project and the preferences of the developer.

Perform Massing Study - [Feasibility] - The design consultant will perform a massing study to determine what a site can hold physically and how the uses layout. This will be based on other factors such as costs, zoning, supply/demand, political will, etc.

Perform Preliminary Market Analysis - [Feasibility] – This task is similar to the task in the previous stage, yet at a more detailed level. The developer now has one or maybe a few sites in mind. The market analysis is conducted with these specific sites and their potential uses.

Prelease – [Preconstruction] – Obtain lease commitments for as much commercial space as possible. Preleasing residential units is more difficult, but if possible, leases should be executed. In a for-sale building presales should be completed.

Procure Major Trade Buyouts - [Construction] - Depending on market conditions, schedule and risk tolerances, the developer may or may not choose procure the major trades prior to a GMP being signed.

Procurement Strategy - [Preconstruction] – A procurement strategy will need to be conducted to determine how the construction GMP and subcontractors are awarded.

Project Closeout - [Stabilization] - This task represents closing all of the contracts with consultants and contractors.

Public Participation - [Preconstruction] - The zoning and approval process will outline if public participation is required for approval of the project. This will vary depending on the local entitlement process.

Punch list - [Stabilization] - As construction nears completion, a list of work to complete items will be generated. Completion of all punch list tasks will signify construction completion.

Reevaluate Organization Strategy - [Feasibility] – The developer will need to evaluate the organization's strategy now that a formal plan is starting to take shape. This plan may or may not be acceptable to the developer.

Refinance / Obtain Permanent Loan – [Asset Management and/or Sale] - The developer will need to refinance the construction loan to a permanent loan. The terms and rates will depend on the capital markets and the amount of space remaining in the building.

Review and Approve - [Idea Inception] – After the project is evaluated and determined that modular construction is possible the developer needs to ensure that the entire team is on board with modular construction and the manufacturer should have the capacity to handle the volume on the time schedule required of the developer.

Review and Approve - [Feasibility] – Once these tasks have been completed, a decision will need to be made of whether or not to proceed with preconstruction.

Review and Approve - [Preconstruction] – Once all these tasks have been completed, a decision is made as to whether or not to proceed with construction, the most financially significant decision made during the process.

Review Design with Engineering Teams - [Feasibility] – The joint review of the developer's initial architectural design concerning the structural feasibility of the project as a modular project with the manufacturer's engineers.

Schematic Design - [Preconstruction] - One of the conceptual designs will be further refined to eventually become a final design. The first incremental milestone on the design timeline is typically referred to as the schematic design. The schematic design will be used for the entitlement process. Depending on the likelihood of changes to design during the approval process, the developer may or may not choose to proceed past this step without some level of consensus.

Secure Anchor Tenant - [Preconstruction] - In many projects, a majority of the space will be taken by a single tenant, known as the anchor tenant. The anchor tenant is obviously the most important tenant and is usually signed during preconstruction. This minimizes much of the lease up risk that occurs after the project has been completed.

Secure Construction Loan - [Construction] - A construction loan will most likely be obtained near the beginning of construction to pay for the work as it is completed.

Secure Construction Loan - [Preconstruction] - A construction loan will most likely be obtained near the beginning of construction to pay for the work as it is completed.

Secure Equity Agreements - [Preconstruction] – Equity will need to be secured during preconstruction to pay for much of the upfront soft costs.

Sell Property - [Asset Management and/or Sale] - The developer may choose to sell the property depending on the organization's strategy and the value of the property in the market place.

Set Modules On-Site [Site Work and Complete Construction Work] – The modules need to be onsite when the crane arrives to begin setting modules. Setting can only occur in good weather so the finishes do not get damaged during the set.

Sign Tenant Agreements - [Stabilization] – In most incidences, tenants will need to be secured during preconstruction to guarantee cash flow after construction. This may not be necessary if equity and debt sources do not require it which is likely be determined by the liquidity and risk tolerances in the capital markets.

Source Materials for Manufacturing – Work with the suppliers to ensure the proper materials are on site at the factory when needed for the manufacturing process. If possible, this should be done on a JIT basis.

Storage of Inventory On or Near Site [Site Preparation & Module Set] – In order to maximize the efficiency of the module set and fully utilize the crane, the modules need to either arrive on a JIT basis or be staged so there is a constant flow of boxes to the crane. In many cases, this involves having the modules sit on site or at a nearby site if space is at a premium, prior to installation. This allows for a tractor to shuttle the boxes from the storage site to the crane for setting.

<u>Third Party Quality Control - [Factory]</u> – This group is required by the state building agencies and is hired by the manufacturer as a quality control agent. This group inspects the plant and the units in the factory once a week to ensure quality. The random sampling and inspection serve as a quality control check – similar to the process used by UL (Underwriters Laboratory).

<u>Transport Modules – [Factory]</u> – The modules need to be transported over the road, in many cases across multiple state lines. The proper permits need to be obtained for oversized loads as well as escorts and police escorts when required. Scheduling needs to be coordinated across all parties to ensure the modules arrive on site when needed. Transportation needs to be arranged so that the proper number of modules is on site when the set crew is there, but enough need to remain at the factory so as not to overcrowd the site.

<u>Update Development Budget - [Site Work & Complete Construction Work]</u> - The development budget will need to be updated throughout this phase as buyouts are completed and as construction progresses. Scope changes and unanticipated design flaws will be paid for out of a predetermined contingency budget. This will need to be monitored throughout the project.

<u>Update Financial Underwriting - [Feasibility]</u> – With further information on rents and costs now available, the financial underwriting can be updated to get a better understanding of the project's financial feasibility.

<u>Update Financial Underwriting - [Preconstruction]</u> – With most information finalized, all financial information is update before construction.

<u>Update Financial Underwriting - [Site Work & Complete Construction Work]</u> - As costs are updated and leases are signed, the developer will want to update the projects operating proforma.

<u>Update Financial Underwriting - [Stabilization]</u> - With all construction costs known and tenants moving in, the financial underwriting will need to be updated to reflect the updated numbers.

<u>Update Market Conditions - [Site Work & Complete Construction Work]</u> - Throughout the construction process, the developer will want to monitor the market to ensure their assumptions made during preconstruction hold true during this lengthy stage.

<u>Update Marketing Plan - [Stabilization]</u> - With space now available (if applicable) the marketing plan will need to be updated. The marketing plan will also be based on the amount of space that is available.

<u>50% Construction Documents - [Preconstruction]</u> - With design approvals mostly complete, full design is underway to get towards constructible documents. Some parts of the building may be completed sooner than others to allow for early procurement of certain trades.

<u>100% Construction Documents - [Preconstruction]</u> - These documents refer to the complete design and structure of the building. However, these documents can be revisited during the production process if changes are deemed necessary. Even though the overall design is complete, the shop drawings for the individual modules will be completed during the production process. The shop drawings always remain a few modules ahead of the production schedule to ensure that any unique circumstances for the individual project are taken into consideration.

Terms in Plain Font: Defined by Bulloch and Sullivan, 2009

Terms in **Bold Font**: Defined by Bonelli and Gonzalez, 2012

Terms in ***Bold Italic Font***: Defined by Bulloch and Sullivan and modified by Bonelli and Gonzalez.

Glossary 2 - Modular Manufacturing Process DSM

Airtight Testing – This test of the plumbing system is required to ensure proper seals and connections.

Approval of Changes – Changes that are made to the design or finishes of the modules made during production are implemented to the modules that have not been produced yet. In very rare cases the changes are made to the completed modules, but this is done at a cost to the developer.

Arrange Drivers and Escorts – Depending on the size of the module being transported, transportation trucks and escort drivers need to be arranged in advance, along with the police escorts where necessary.

Assembly Mix Established – Each module is different and the complexity varies. To ensure efficient production, the production of modules needs to be varied so that there is a balance between the complex and simple modules. Workers are more efficient when difficult tasks can be broken up by simple tasks.

Bath Installation – The various bath fixtures (i.e. tubs and shower pans) are installed according to the plans.

Begin Manufacturing of Modules – The start of the manufacturing of a given project or module.

Connecting All Utilities – All utilities and systems (sewer, water, electrical, gas) need to be connected to the main lines that were installed during the site preparation work.

Determining On-site Storage– Modules need to be staged in a way to effectively and efficiently set the modules once the crane arrives. The crane can cost approximately $3,000 - $7,000 per day and ensuring there are modules on site for the crane to install is critical to minimizing the time the crane is on site.

Doors shut and locked – The unit is locked to prevent any person or animal from entering the unit while in storage in the factory yard or staging area.

Documentation of Process – In an ideal process the checks and inspections of the modules as they move through the factory will be done on an electronic device where all the issues are stored in a database and photo evidence of all inspections are completed and stored.

Documentation of Issues and Solutions – As the modules go from station to station in the factory quality control checks that the plans are followed and notes any issues on a quality control card. These issues are then corrected at either the current stage or the next stage depending on the factory's schedule and time required for the correction.

Drywall installed – The drywall or gypsum board is installed on the interior walls of the module. The joints are taped and spackled, then sanded to a smooth finish.

Exterior Sheeting Applied – The exterior sheeting is applied to the exterior walls of the module and a home wrap is installed to prevent wind and moisture from entering the structure.

Final MEP Inspections – The final inspections need to be completed by the local building inspector to ensure all systems and connections satisfy the local building code. Once the inspections and approvals are complete, the certificate of occupancy can be issued.

Final Approval – All parties are involved and agree that the building is ready to be turned over to the developer or property manager. The tenants are ready to move in and the punch list is complete.

Finished Flooring Installed - The finished flooring is installed. If hardwood floors are installed, the flooring is only installed in one module and installed on site in the adjoining module to ensure a smooth transition from room to room.

Fixture Installation – The lighting and plumbing fixtures are installed. Any hanging fixture that has the potential to swing or get damaged during transportation or installation will be placed in the unit for on-site installation.

Floors covered – A protective covering is installed over the flooring to keep it clean during transportation, installation and final connection of the systems onsite.

Foreman assigns Work Teams – Various crews are assigned to the different stages of production. "Specialist" crew members are dedicated to one activity, while others are considered "floaters" and go where the work is needed. Floaters tend to be more productive than the specialists due to the variety of work being performed.

Foreman assigns "Lead Man" – A lead is assigned to each stage. This worker is responsible for completing the task for the given stage and getting the box to the next stage on schedule.

Foundation Construction – The foundation of the building needs to be poured prior to any modules arriving on-site.

Head of Engineering oversees project – The engineer for the manufacturer is responsible for ensuring the engineering of the structure is proper and meets all the appropriate codes.

Implementation of Changes – All changes made during the mockup viewing are implemented in the ordering and production process. *This step only occurs for the first unit.*

Insulation is installed – Fiberglass insulation is installed between the studs and a vapor barrier is installed. If dense-pack insulation is used, the drywall is installed over the vapor barrier first and a thin, see through felt-like material is installed on the exterior wall. The dense-pack insulation is blown in each cavity and the worker can visually determine how much insulation has been blow in to ensure the proper R-factor is achieved.

Kitchen Installation – The kitchen cabinets and countertops are installed. In certain cases the countertops are installed on site due to potential damage to more expensive materials. Appliances are typically installed on site to save on shipping weight and avoid damage.

Lead CAD Designer Appointed– Project coordination is more streamlined when one CAD designer is assigned to the project. One designer can be aware of all changes and idiosyncrasies of the project. Scale is obviously an important consideration, but for multifamily projects of approximately 50 units, this is not an issue.

Lead Foreman assigned to Project – A lead foreman is assigned to the project. This person is responsible for the production of the modules, the quality assurance, the assignment of the crews, and the order in which they are produced. The modules are produced so that modules that require more labor are intermixed with those that require less to ensure efficient production and it prevents the workers from burning out by doing the same type of module over and over.

Lumber Check and Approval – The lumber arrives on site and is inspected and sorted by the grade. The highest quality lumber is used for the building of the modules, while the lower quality lumber is used for the shoring of the module where the lumber will be cut out after the module is set on site.

Mill Work Cutting – The mill work station receives the lumber and cuts it to the desired specification for that module. The lumber produced from this stage is labeled with the module number and placed in a wheeled bin that is delivered to the various production stages.

Modular Construction "Kick-Off"– This is the point at which the production scheduling for the building takes place and the process actually begins at the factory.

Mockup Assembled, Viewed and Modified – A mockup unit is assembled on site for the various members of the team to walk through. This is the very first unit for the building that is produced. This unit is used for the actual building. This is an essential part of the process for a multifamily building so that finishes and minor adjustments can be made prior to the production of the units. Visually seeing the units is an important step as many members of the team can see and understand what the decisions made earlier translate to when in the actual unit. Any modifications deemed necessary by the team after the mockup viewing are made and incorporated into the design and drawings. *This step only occurs for the first unit.*

Modules sealed and packed – The module is sealed with a weather resistant shrink wrap tarp to protect it during storage and transportation.

Modules completed and stored - Once the modules are complete they are put in a storage area and staged for delivery while the other modules are being constructed. This is an important element of the process so as not to overwhelm the site prior to the set date.

Obtaining Occupancy Permits – Once the final approvals are completed by the building inspector the occupancy permits are issued and tenants can begin moving in and the developer can begin collecting rents.

Obtain Proper Permits by State – The units need to obtain the proper permits and documentation for transportation across state lines. According to Federal Law, oversized loads must travel on the most direct route possible and must meet the laws and regulations of each state it is traveling through. Some states only require a vehicle escort and others require a vehicle and police escort.

Perform Interior and Exterior Finishes – The siding and exterior finishes are installed to ensure the all seems are straight and the building doesn't appear to have been assembled by a number of boxes. The interior finishes are installed, the mechanical connections are covered in the corridors, and the paint carpet, tile, etc. are installed to finish the interiors.

Platform Construction/MEP Systems– Construction of the module begins by setting the lumber on a steel jig. The floor perimeter and joists are installed to prepare it for the flooring. The platform is constructed and the other components of the module are laid out. This includes the MEP systems which are prepared for installation once the walls are installed and become part of the structure. The sub-floors are installed as a final step before installing the walls.

Primer Paint Coat Applied – The walls are sprayed with a primer so the units are ready to receive the color paint the owner chooses on site. Finish painting can be done in the factory, but it is recommended to do this on site once the building has settled for approximately 1 year.

<u>MEP and Overall Systems installed</u> – The wiring and piping is installed along the beams and joists according to the specifications detailed in the plans. These items are then run up to the various areas that require connections and the holes are fire stopped. The outlets and receptacles are installed and connected to the appropriate wire and pipes are cut or capped at their termination point.

<u>On-site Oversize Load Issues</u> – Urban sites have issues with receiving oversized loads. Coordinating street closures and other transportation issues with the town must be done to efficiently install the modules on site.

<u>Roofing is constructed and installed</u> – The roof and/or ceiling, depending on the height of the module is constructed at a separate station. It is then lifted and installed on the module.

<u>Select Set Crew</u> – The manufacturer selects the set crew to install the boxes. This crew is dedicated to installing the boxes and "assembling" the building. A proper and speedy set not only reduces the crane costs, but it also ensures securing the modules together is done properly. The connection of the systems is done by other crews (hired subcontractors).

<u>Select Site Crew (Subcontractors)</u> – The site crew is responsible for finishing the building once the modules are set. These crews will finish all MEP, finish, landscaping work, etc.

<u>Set modules</u> – The modules arrive on site and are set in place by the crane and set crew.

<u>Secure modules</u> – The modules are stacked one on top of each other in a column, bolted together using a variety of bolts and screws and secured with hurricane strapping in a tic-tac-toe pattern at each corner. Once a column is complete, the column next to it is stacked and bolted to the column just installed.

<u>Shop Drawings given to Designated Worker</u> – Detailed shop or production drawings are given to the workers at each stage for the proper construction of the module and their assigned task.

<u>Shop Drawings designed</u> – Modules vary and can be complex or simple, heavy or light, just to name a few variances. The specific drawings for each module need to be provided to the production floor so the workers can properly build the boxes and ensure a proper fit and connection to the other modules once on site.

<u>Sourcing of all materials</u> – The materials for the production of each module needs to be sourced and on site at the time of production. Many of the more specialized items such as faucets, cabinets, and fixtures are ordered on a Just-in-Time basis to reduce inventory costs.

<u>Tasks assigned to "Floaters" or "Specialists"</u> – Tasks based on the plans are assigned to the workers in the plant. This is repeated throughout the production process and depends on what type of module is on the factory floor at any given time.

<u>Third Party Inspection</u> – A third party inspector comes to the factory on a periodic basis to further ensure quality control. While every module is not inspected, the units on the factory floor at any given time are inspected to ensure they are being assembled according to the plans and construction documents. The modules being inspected may or may not be part of the particular project the third party inspector was hired to inspect.

Transport Modules to Site – The modules need to be either brought directly to the site or to a staging area near the site where a tractor will shuttle back and forth and bring the modules to the site for the crane to pick and install the module.

Utility Connections – The utilities need to be piped in and installed at the same time the foundation is being poured and prior to the modules arriving on site.

Weatherproof Modules – The connections where the modules come together are wrapped with a home wrap to prevent wind and weather from entering the structure.

Window, Door, and Trim Installation – The windows, doors and interior trim are installed. The exterior walls are sealed and flashed to prevent water from entering the unit through the seam. The exterior siding and trim are installed on site.

Walls are constructed and erected – The walls are assembled at a separate station and lifted overhead and installed on the completed platform.

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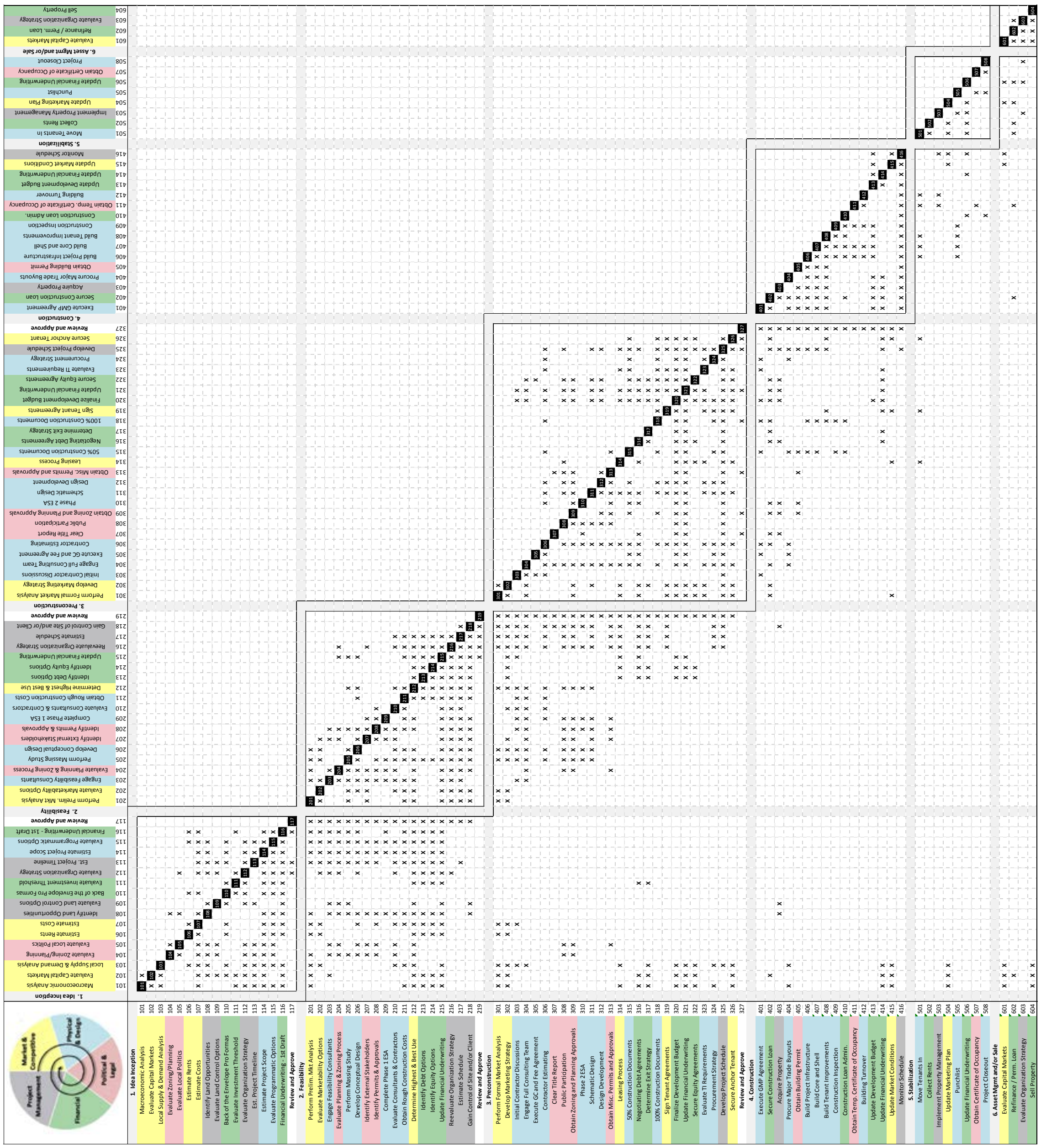
Appendix 1 – Bulloch and Sullivan Baseline DSM



Appendix 2 – DCF Analysis

Discount Cash Flow Analysis - Modular Construction Hypothetical Multifamily Project

General & Scheduling Info		Income & Expenses	Amount	PSF
Total Square Feet	60,000 sf	Market Rent		$39.00 psf
Leasable Sq Ft	51,000 sf	Rent Growth Rate		3.00% /yr
Site Acquisition	2,750,000	Construction Costs		
Closing Costs	2.00%	Hard Costs	$11,100,000	$185.00 psf
Vacancy Factor	5.00%	Soft Costs	$2,775,000	$46.25 psf
Project Kick-Off	Month 1	Additional Delay Costs	$0	$0.00 psf
Construction Start	Month 6	Operating Expenses	$8,000	$8 per sf
Construction Finish	Month 18	Fixed Expenses		$0.00 psf
Lease Up Start	Month 16	Variable Expenses		$0.00 psf
Lease Up Period	8 Months	Expense Growth Rate		2.00% /yr
Free Rent	0 Months	Leasing Commissions		$3.25 psf
Avg Unit Size	1,025 sf	Tenant Improvements		$0.00 psf
Total Units	50 units	Equity Requirement - 35%	$	5,838,000
		Capital Reserve		$1.25 psf
		Total Cost	16,680,000	$278.00 psf

Construction Loan			Exit	
Loan to Value		0%	Sale Month	Month 144
Amortization		0 Years	Terminal Cap Rate	7.00%
I/O Period		5 Years	Exit NOI	0
Constr. Loan Int R	spread over libor	4.75%	Sale Price	0
Constr. Loan Fee		1.00%	Cost of Sale	2.00%
Payoff Date		Month 26	Sale Proceeds	0
Proceeds		10,842,000		0
Refinance				
Loan to Value	80 max	70%		
Amortization		20 Years		
I/O Period		0 Years	Cap Rate	6.50%
Loan Proceeds		0	Valuation	0
Interest Rate	spread over 10 yr	4.5%		
Commencement		Month 26		
Payoff Date		Month 144		
Fee		1.0%		

Year #	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12
Leasing Schedule													
SF Leased	0 sf	0 sf	51,000 sf	51,000 sf	51,000 sf	51,000 sf	51,000 sf	51,000 sf	51,000 sf	51,000 sf	51,000 sf	51,000 sf	51,000 sf
Capital Events													
Site Acquisition	2,750,000	-	-	-	-	-	-	-	-	-	-	-	-
Acquisition Closing Costs	55,000	-	-	-	-	-	-	-	-	-	-	-	-
Gross Acquisition Cost	(2,805,000)	-	-	-	-	-	-	-	-	-	-	-	-
Disposition Price	-	-	-	-	-	-	-	-	-	-	-	-	30,532,821
Disposition Closing Fees	-	-	-	-	-	-	-	-	-	-	-	-	(610,656)
Net Sales Proceeds	-	-	-	-	-	-	-	-	-	-	-	-	29,922,164
Total Capital Events	**(2,805,000)**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**29,922,164**
Development Costs													
Construction													
Hard Costs	(2,805,000)	(6,475,000)	(4,625,000)	-	-	-	-	-	-	-	-	-	-
Soft Costs	-	(1,958,824)	(816,176)	-	-	-	-	-	-	-	-	-	-
Additional Delay Costs	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Development Costs	(2,805,000)	(8,433,824)	(5,441,176)	-	-	-	-	-	-	-	-	-	-
Operating Budget													
Potential Gross Income	-	-	961,370	2,146,469	2,211,756	2,279,028	2,348,347	2,419,774	2,493,374	2,569,212	2,647,357	2,727,879	2,810,850
Vacancy	-	-	(17,577)	(107,323)	(110,588)	(113,951)	(117,417)	(120,989)	(124,669)	(128,461)	(132,368)	(136,394)	(140,543)
Leasing Concession/Commission	-	-	(102,685)	(28,506)	(33,150)	(33,150)	(33,150)	(33,150)	(33,150)	(33,150)	(33,150)	(33,150)	(33,150)
Effective Gross Income		**-**	**841,108**	**2,010,639**	**2,068,018**	**2,131,927**	**2,197,780**	**2,265,636**	**2,335,555**	**2,407,602**	**2,481,840**	**2,558,335**	**2,637,158**
Operating Expenses	-	-	192,875	430,636	443,734	457,231	471,138	485,468	500,234	515,449	531,127	547,282	563,928
Total Operating Expenses		**-**	**192,875**	**430,636**	**443,734**	**457,231**	**471,138**	**485,468**	**500,234**	**515,449**	**531,127**	**547,282**	**563,928**
Net Operating Income (NOI)	**-**	**-**	**648,233**	**1,580,003**	**1,624,283**	**1,674,696**	**1,726,642**	**1,780,167**	**1,835,321**	**1,892,152**	**1,950,712**	**2,011,053**	**2,073,230**
Operating Capital Costs													
Capital Reserve	-	-	29,219	63,750	63,750	63,750	63,750	63,750	63,750	63,750	63,750	63,750	63,750
Total Operating Capital Costs		**-**	**29,219**	**63,750**	**63,750**	**63,750**	**63,750**	**63,750**	**63,750**	**63,750**	**63,750**	**63,750**	**63,750**
Unlevered Cash Flow	**(2,805,000)**	**(8,433,824)**	**(4,827,342)**	**1,516,253**	**1,560,533**	**1,610,946**	**1,662,892**	**1,716,417**	**1,771,571**	**1,828,402**	**1,886,962**	**1,947,303**	**31,931,644**
Present Value	**(2,805,000)**	(7,976,196)	(4,392,157)	1,238,300	1,176,669	1,121,590	1,069,028	1,018,873	971,018	925,364	881,812	840,269	12,294,187
Net Present Value	**6,363,758**												
Financing													
Loan Proceeds	-	5,400,824	5,441,176	16,863,375	-	-	-	-	-	-	-	-	-
Loan Draw / Proceeds	-	-	-	-	-	-	-	-	-	-	-	-	-
Interest Payments	-	(42,271)	(439,781)	(727,087)	(677,964)	(649,702)	(620,141)	(589,222)	(556,883)	(523,059)	(487,680)	(450,677)	(411,973)
Principal Payments	-	-	-	(10,818,262)	(615,200)	(643,463)	(673,023)	(703,942)	(736,281)	(770,105)	(805,484)	(842,487)	(806,237)
Final Principal Payment (Perm)	-	-	-	-	-	-	-	-	-	-	-	-	(9,726,985)
Total Cost of Financing	-	5,358,553	5,001,396	5,318,026	(1,293,164)	(1,293,164)	(1,293,164)	(1,293,164)	(1,293,164)	(1,293,164)	(1,293,164)	(1,293,164)	(10,945,196)
Levered Cash Flow	**(2,805,000)**	**(3,075,271)**	**174,054**	**6,834,279**	**267,369**	**317,782**	**369,728**	**423,253**	**478,407**	**535,238**	**593,798**	**654,139**	**20,986,448**
Present Value	**(2,805,000)**	(2,962,141)	145,528	5,744,720	201,396	221,061	237,514	251,085	262,073	270,751	277,367	282,148	8,071,353
Net Present Value	**10,197,855**												
DSCR Ratio		0.00	-0.13	-0.30	1.26	1.30	1.34	1.38	1.42	1.46	1.51	1.56	0.19