Rochester Institute of Technology
Manufacturing & Mechanical Engineering Technology

SYSTEMS ENGINEERING AND URBAN PLANNING

The Application of Systems Engineering Techniques to the Process of Urban Planning

Manufacturing and Mechanical System Fundamentals
MFET – 650 – 01
FALL SEMESTER 2017

PREPARED BY: Scott Bell
INTENDED FOR: Prof. Richard Share

Date Submitted: 11/21/2017

Page intentionally left blank.

Table of Contents

Table of Figures

Abstract

Urban Planning has seen violent evolution since it's recognition as a profession over a century ago. In this time, the occupation has seen the development and abandonment of many theories and methodologies that try to fit the overly vague definition of the roles and responsibilities of an urban planner. These methodologies, eight of which are discussed in this paper, each have a certain focus, but each include disadvantages that may prevent the dedicated use of one methodology. The mixing of these theories in the planning committee of a municipality creates confusion. This paper theorizes that the methodology followed by systems engineers may produce the flexibility that is necessary in the planning profession while also decreasing the disadvantages seen in the eight popular methodologies addressed previously. The areas of focus are the (1) framework developed by parallels between the urban planning methods and system engineering methods, (2) advantages of needs analysis in the physical, economic, and social realms of urban planning, (3) ability to recognize and diagnose interactions within the subsystems of a city, (4) increased understanding of the hierarchy of the city as a system, and (5) necessary application of an iterative process to address the constant changes occurring in an urban environment. Excluding a few hesitations of implementing the systems engineering method, it is found that this process has the potential to significantly improve the current urban planning procedure.

1 Introduction & Background

1.1 What is Urban Planning?

Urban planning is defined in the Encyclopedia Britannica as the "design and regulation of the uses of space that focus on the physical form, economic functions, and social impacts of the urban environment and on the location of different activities within it" [1]. Most definitions of urban planning follow this pattern, using broad mentions of the three main realms of concern of an urban planner; **physical, economic,** and **social**. While this definition is vague and diverse in the nature of this occupational process, it can be broken down into a few main factors. First, the term *urban planning* is said to deal with the "design and regulation" of public and private spaces. The goal of this is to rationalize the placement of both public and private city features. The process used to decide the purpose of the designated land varies per city but there are multiple theories of planning with similar characteristics discussed later in this paper. Second, this definition states that urban planning focuses on "the physical form, economic functions, and social impacts" of the urban environment they create. This is an interesting concept because the committees and teams that deal with the planning tasks of townships and cities must balance their plan in the current environment created by the decisions of the past committees and teams, as well as the environment they propose in the future. This balance is key to success – if their plan does not align with the current strategy of the city, then there will be little chance of a successful implementation, but if their plan is stagnant in the predicted environment and does not promote changes to better the city's standing in all three of the aforementioned realms, then the city itself may not have an available framework for growth. Third, the definition finishes by stating that the location of each activity is within the concern of an urban planner. This definition's conclusion is lacking one feature that would make it more robust: a mention of the process used to develop the "different activities within [the city]." Based on the literature reviewed for this research, the urban planner is also concerned with the process in which these different locations are chosen and allocated. Allocation is an important feature of this position, as the zoning ordinances of a city are decided by these urban planning teams. For this paper, the definition of urban planning will include the process of these decisions as well.

While cities themselves can easily be considered a complex system, or even an acknowledged system of systems, the main concern of this paper is to dive deeper into the procedure behind urban planning and focus minimally on the resulting municipality formed by the process. To contrast the two, we can draw analogous ties to the difference between a functioning system and the systems engineering method with regard to the goals of each.

The first is a complex and designed arrangement of components working together towards a **unified goal**. In systems, this goal is often noted by the initial meetings with a customer, whereas the city has a less professionally defined goal. Through reading literature related to the formation of cities, there are a plethora of theories and hypotheses as to the driving force behind developing cities. Two main themes commonly emerge despite these differences in initial theories. The first is that of the more humanitarian outlook on human interaction. The idea is that cities start by developing through the social needs of the human population. Naturally, most arguments for this idea are tied to early developing populations such as tribes and settlements created when people are isolated in an unpopulated area [2]. While this theory has valid arguments to the innate pack-nature of humans, it has very little ground in discussing the organized patterns in planning an established municipality.

The second idea behind the growth of cities is the economic benefit behind them. In the article published by Bluestone, *Key Factors in Urban Economic Growth,*

> "For most cities and towns, economic prosperity rests on the ability to retain and attract business investment and the jobs and the tax revenue that this investment generates. Municipalities with robust commercial and industrial activity generally have higher rates of employment, less joblessness, higher household incomes, and the wherewithal to support a rich array of public services" [3].

This article (along with many others) specifies economic opportunity as a key contributor to the growth of a city. When stated that a city is a complex system, we can generally conclude that the similar goal is that of economic benefit.

The second is a process rather than a functioning system. The unified goal of economic benefit discussed above is not the same for this process: rather than having the goal of economic prosperity, urban planning will define a set of strategies that will accomplish this goal. Put simply, rather than saying "this plane will fly," we will say "these are the steps and strategies to create a flying machine." It is this consideration of the process that the relatively new field of systems engineering could amend if applied correctly. The field associated with city planning and strategic development is also a relatively young process, and has run into many similar problems.

1.2 Brief History of Urban Planning Processes

The ideas behind city planning have developed over millennia. There is evidence that roles in designating land use and no-build zones existed in the ancient Mayan and Aztec populations in Mexico (with reasoning based in the layout of astrological sites and north-oriented buildings [4]), as well as in Ancient Rome and Greece (with reasoning based in the orthogonal layout found often in current towns and cities [5].) With that being said, there is little historic documentation on the strategy, and most strategy is either assumed or derived from the apparent layout of the towns and accompanying roads. Looking forward, academic courses were developed in this discipline in 1909 in Great Britain, and in North America in 1924 [1]. As this instruction emerged, many variations also materialized. In the mid 1900's, the two dominant themes echoed the two perspectives in the formation of a city discussed in section 1.1. Some programs focused on the more traditional ideas of allocating land and how to produce a remunerative city while others looked deeper into the social sciences behind the politics in a municipality and how they address current issues.

In an essay published in 1962, it was stated that there was much confusion in the roles and responsibilities of the town board in the planning process [6]. The cause of this was traced to an excessively vague definition of urban planning that included an unexplained requirement for a "master plan." As similar problems cropped up around the country, an "ideal planning method" was sought, and many scholars in this profession attempted to develop such a method. The problem with this is that there was a significant divide between the theories devised and the possibilities realistically available in practice. The University of Pittsburgh published a paper by Oner that discussed this gap between theory and practice [7]. Research in the planning profession was being conducted as a "descriptive social science" instead of a theory that was "grounded in practice." Oner developed a sound summarization of the types of planning found across a number of established planning agencies. She identified 8 planning theories that were similar across many of the agencies, and 7 descriptors that

show distinctions in each of the theories. (A more detailed description of each of these relationships can be found in the literature of Oner, pgs. 41-90)

PLANNING THEORIES

- Comprehensive Land Use Planning
- Rational Planning
- Allocative Planning
- Advocacy Planning
- Incremental Planning
- Middle-Range Planning
- Innovative Planning
- Radical Planning

DISTINCT FACTORS

- Motivating factors of the theory
- Objective of the theory
- Major concerns of the theory
- Major values of the theory
- Ideology behind the theory
- Role of the planner
- Origin of the theory

These theories are not strictly independent though; some emerge as a combination of two theories, while others may be branches of a more established theory. For example, allocative planning can best be described as a combination of comprehensive land use planning and rational planning, while radical planning is a more extreme version of advocative planning. These relationships can be seen below in *Figure 1.*

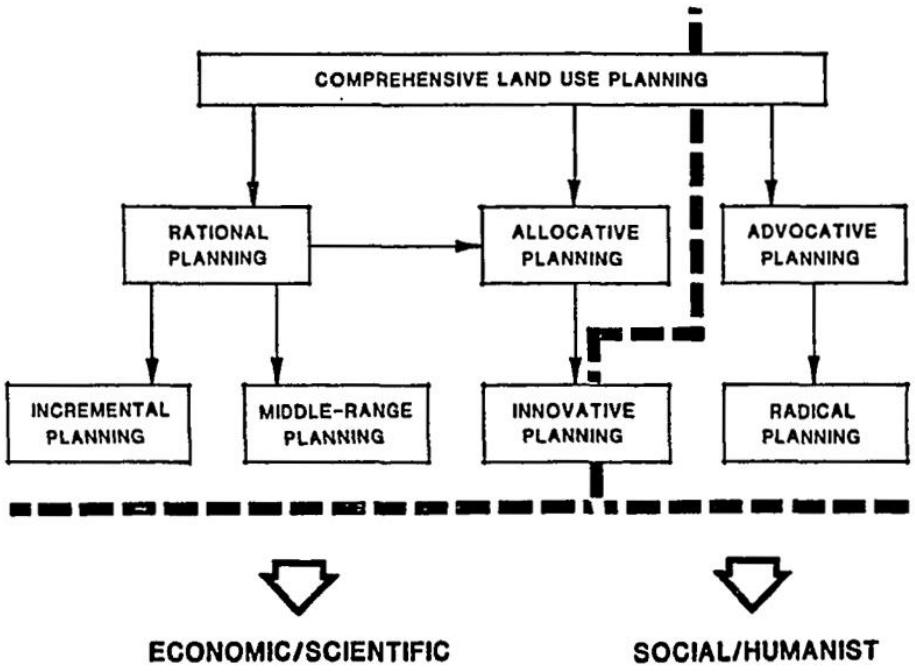

Figure 1 *- Relationships and observed trends of 8 major planning theories [7]*

Shown above (dotted line) is a delineation between the economic/scientific and social/humanist concentrations of each method, again echoing the two perspectives of city formation discussed above. The 8 theories each have their drawbacks, though. There is not a solution as to which method is supreme to all others. They all stem from the traditional form of comprehensive land planning, but this progenitor perpetuated its problems through the branches of these theories.

1.3 Discontinuities in the Modern Urban Planning Process

Each of these widely accepted theories has advantages and disadvantages. These theories all differ with respect to the seven factors above as well, but, for the sake of this description, we will focus on just the heavily abbreviated benefits and downfalls of each [7].

1. **Comprehensive Land Use Planning:**
   Advantages: provides a physical goal and planned city layout, planning *for* the people.
   Disadvantages: is not responsive to changing urban conditions, weak methodology.
2. **Rational Planning:**
   Advantages: aims to maximize profit to the city, focuses on process, moderately strong method.
   Disadvantages: does not define success, only focuses on raising status, poor social engagement.
3. **Allocative Planning:**
   Advantages: provides an end-goal, aims to balance economic growth *and* social development, defines success, distributes government resources across needs efficiently, closely tied to budget.
   Disadvantages: Poor reaction to changing urban conditions, rarely considers citizen input.
4. **Advocacy Planning:**
   Advantage: defines needs using input, focuses on how plans impact society, planning *with* people.
   Disadvantages: costly, time consuming, weak methodology, known to cause debate between interest groups.
5. **Incremental Planning:**
   Advantages: defines success and method simultaneously, focuses on predicted results before ruling out ideas, reactive to changing urban conditions. (antithesis to rational planning)
   Disadvantages: counts on continuous policy-making process, very idealistic, requires high degree of control, which is not often found in developing cities, very slow and time consuming.
6. **Middle-Range Planning:**
   Advantages: Balances short-term and long-term planning strategies, defines scope and refines plan as it progresses, patterns identified in past projects and policies, strong methodology.
   Disadvantages: weak considerations for citizen input, often complimentary to another planning style, relies heavily on experienced team.
7. **Innovative Planning:**
   Advantages: self-guided approach for different city sectors, focuses on turning ideas into actions and policy, uses experimentation to develop predictions.
   Disadvantages: weak effort given to older programs, temporary in nature – best used during rapid change.
8. **Radical Planning:**
   Advantages: very responsive to social demands and urban changes, easily adaptable, brings planning committee closer to people they are planning for; planning *by* the people.
   Disadvantages: still much debate on effectiveness, costly, requires large amount of group/citizen input.

Because of the variation in the benefits and drawbacks of each of these theories, no single theory can be considered the be-all-end-all method. Often, planning committees achieve success through a combination of approaches, fluidly (or not so fluidly) moving between planning theories based on the type of problems that they are trying to solve [8]. *What if there was a method that was able to incorporate each of the above theories on planning with as few trade-offs as possible?*

2 Research Topic

2.1 Process Comparison: Identifying Preexisting Parallels

Often regarded as entirely separate occupations, systems engineering (henceforth abbreviated as SE) and urban planning are not that far apart in scope and many parallels can be drawn between the two trades. For this paper, the models used will be primarily INCOSE models. Any other SE models or figures from alternate sources will be cited accordingly.

Implementing the SE method for this application would prove to be exceptionally useful because it would, **(a)** provide a unified methodology for needs analysis in each of the three realms defined in section 1.1, **(b)** help recognize interactions and interfaces between these realms, **(c)** denote the benefits of defining the hierarchy of the city as a system, and **(d)** provide a reiterative structure that includes testing and evaluation to adapt to changes in the urban environment. It is hypothesized that this approach would be moldable to incorporate the advantages of all eight theories of urban planning and alleviate many of the disadvantages that are inherent to each method. To create a framework to support these hypotheses, we must first explore the current attributes that are common to both professions. The SE process as outlined by INCOSE *(Figure 2)* will provide the basis by which we are able to make our comparisons.

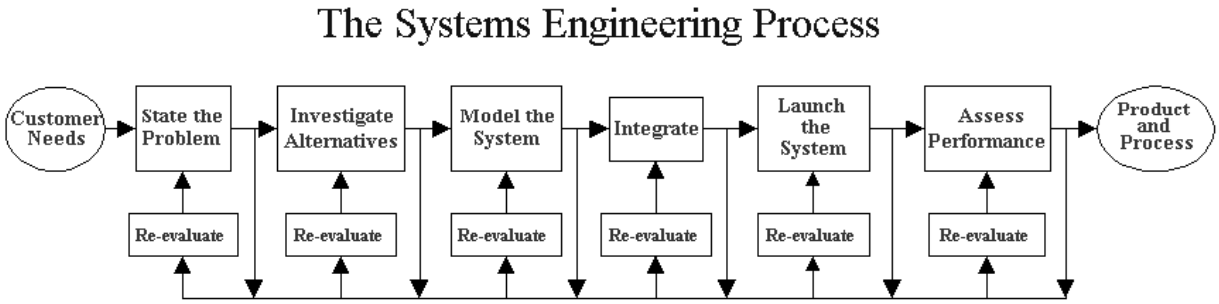

***Figure 2** - INCOSE Systems Engineering Process (reproduced for clarity from [9])*

2.1.1 Customer Needs

The customer plays a significant role in the typical SE process. They are the ones who are experiencing the problem and have developed a need for a solution. In the case of urban planning, there is not one, but many customers that must be satisfied with the result. The first divergence from the SE rationale appears when the customer base is defined. The customers and stakeholders of a city plan consist of the community members, the developers, and leading agencies tasked with carrying out certain portions of this plan [10]. This diverges from the SE method because it is normally understood that the customer has a single set of needs. In the scope of city planning, many interest groups exist, and it is possible, if not likely, that some of these interest groups may have conflicting needs. Rather than developing a single set of customer needs, the committee must define a set of needs that satisfies a *majority* of the customers and stakeholders.

2.1.2 State the Problem

A well-defined problem is key to developing an adequate solution. In an SE environment, the problem is normally derived from operational deficiencies of a predecessor system. The same is usually true for cities. In a sample city plan from Orlando, Florida, policy 2.1.5 states that, "The City shall coordinate with the School Board to research and identify alternative planning and funding mechanisms to provide sufficient school capacity for future growth" [10]. Orlando's policy indicates predicted growth past what their school system is able to manage. This will create a deficient school system and thus a need for "alternative planning and funding mechanisms." This is one of many problems that require attention due to an outdated or deficient system. Municipalities encounter deficiencies and/or problems in copious amounts, which is why a plan is essential to address all of them. Well-defined problems also influence cost. If the citizens are concerned about a particular roadway's integrity, the committee can phrase the question in one of two ways: the first way could call simply for pavement patchwork, while the second way could call for a complete reconstruction of that roadway. This is where the city must be careful in defining the problem. If the roadway is failing mechanically, then patchwork will only waste money before a complete reconstruction is needed. On the other hand, if only patchwork is needed, then a complete reconstruction would be an excessive waste of money that could have been allocated to another project. While this is a simple example, the same ideas can be applied to much larger issues such as affordable housing or intracity transportation. The problems faced by the planning committees need to be as well-defined as they are for the SE method in order to form an effective solution.

2.1.3 Investigate Alternatives

Known by many as concept development, investigating alternatives is important to any problem-solving task, but truly imperative to the SE method in order to achieve a solution that satisfies all the criteria. This idea of imperative concept exploration also applies directly to urban planning. In choosing a solution, the city must balance the same general factors as an engineered system. Performance, budget, schedule, and associated risk are all factors that need to be considered before narrowing in on a solution. Of course, each criterion also needs to be related to the needs of the customer, and in terms of the urban planners, the majority of the customers. These additional criteria are similar in almost every regard to the criteria developed in an SE process. The clear advantage to the SE method is that it promotes the use of tools that allow for the clever distribution of resources in terms of these important factors. Decision-making tools such as these may provide the urban planning profession with more in-depth information and allow better informed choices. This includes advantages for both the Rational (budget-centric allocation) theory of planning and the Allocative (Resource-centric allocation) theory of planning.

2.1.4 Model the System

In systems engineering, modelling could mean anything from back-of-the-envelope sketches to functional engineering units. Complex systems usually result in many models, although few, if any, are comprehensive. This holds true with urban planning. Whether the solution is a project to increase the job availability within the city or the plan for a new overpass, urban planners will outline the process using strategies most effective for the type of problem. Recently, the advancement of technology has increased the capability for urban planners to participate in simulations similar to those that were previously only available to mathematicians and scientists. These advancements are showcased in a number of new softwares appearing on the market. In an article by the American Planning Association,

The UrbanSim Cloud platform allows for strategic planning through the use of detailed simulations including current traffic patterns, development plans for land use, and even zoning policy changes' effect on residential area growth [11]. The simulations run in this software are analogous to the analytical simulations run in an SE project. These models answer the question, "what would happen if..." and give valuable feedback to the decision-making process in both urban planning and SE scenarios.

2.1.5 Integrate

This has the connotation of being a very physical step in the INCOSE model of the systems engineering process. Naturally, integration brings up the thought of assembly and manufacture, and if this were strictly a complex engineered system, this thought would be mostly correct. To apply this to the profession of urban planning, our definition needs to be a bit more abstract. The integration step of the SE process begins to look at how everything will work together. In urban planning, this notion of integration more closely follows the assimilation of agencies responsible for carrying out the plan. These agencies could be general contractors for buildings, governmental legislative bodies for new environmental standards, or even citizens who are participating in volunteer work (e.g. Habitat for Humanity housing developments). During integration, the planners should look at the type of plan being implemented and focus on congregating the agencies that will be responsible and validating that each will be able to complete their part of the plan or project.

It is important to also look at the interactions between each of the plans the committee develops. The plans made up to this point should start to look into possible interactions between multiple systems as well. Unfortunately, as found by Oner in her study of 50 planning agencies, planners often "overlook crucial communications between the implementation of plans that significantly affect one another" [7]. Imagine a bus route and a new traffic pattern due to road construction in the downtown area of a city. The bus route has been in place for five consecutive years with no changes, but a certain roadway downtown is being repaired. When this road is closed, much of the traffic that normally travels it needs a detour. Without focusing on the interactions between these two systems, the detour could be accidentally routed through parts of the city that rely on bus stops, creating traffic jams and backups that would increase risk for accidents as well as decrease accuracy of the bus schedule. Recognizing these relationships early in the SE process will help put in place a more strategically effective plan, and is discussed later as a possible benefit to the urban planning & SE theory that this paper plans to develop.

2.1.6 Launch the system

When a plan is fully defined in strategy, and it is supported, it must be approved. The approval process is not only different across most states, but also may vary from town to town. For the simplicity of this document, we will look at a single method of approval followed in New York State *(shown in Figure 3)*. This flowchart depicts the particular process of receiving town or county approval for any new plans for a build site [12]. This process requires a final plan to be submitted to the stakeholders. This plan is reviewed and possibly modified in a public hearing, then sent to the legislative planning board for further modifications. At this point, the board will either approve, approve with conditions, or disapprove of the plan. If the plan is disapproved, another submission must be made. This process is similar to the United States Department of defense's critical design review (CDR) as outlined in the DoD Acquisition Guidebook. The CDR is an event during which the stakeholders make sure that each item satisfies requirements for cost, schedule, and performance [14]. The DoD's CDR also looks into

the risk of the system and assesses the necessary equipment to run the system (i.e. facilities, software, personnel, etc.) Like the approval process aforementioned, if any modifications need to occur, then they will be addressed during this event. Again, despite having few academic ties to systems engineering, urban planning draws another visible parallel and strengthens the framework created in this section.

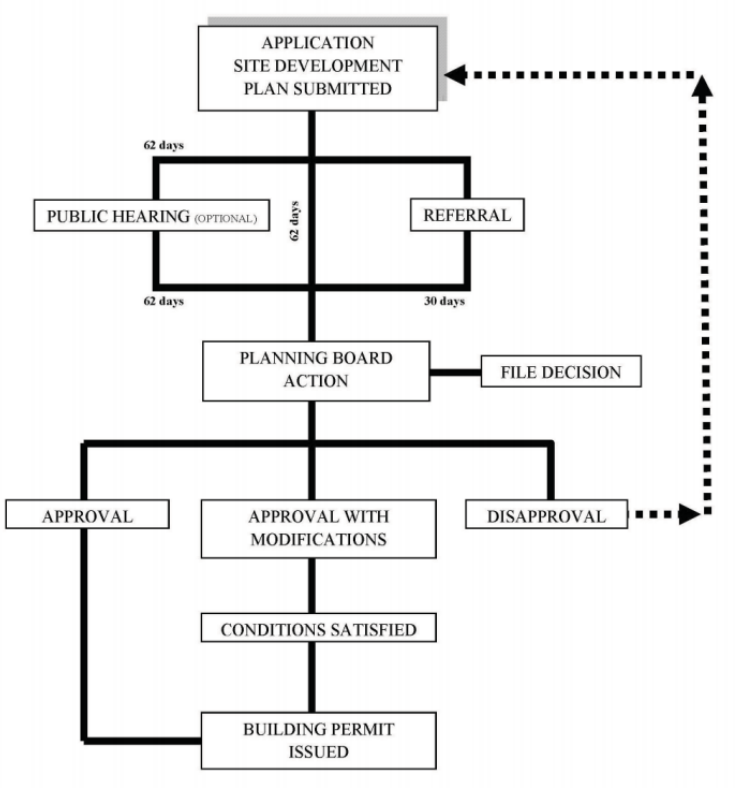

Figure 3 *- Approval process of permit issuance specific to New York State municipalities. [13]*

2.1.7 Assess Performance

During an engineered system's operation, valuable feedback is obtained from those who use and benefit from the system's purpose. This feedback, depending on the system, could produce ideas for the next system or product, an updated modular fix for the system or product, or identify a feature that was highly regarded and could be used to make other systems successful. In a planning scenario, this could be the feedback obtained from the citizens about turning a vacant plot of land into a park. Granted, these responses are late in the process. Of course, over the lifetime of a valid city plan it is amended multiple times to account for changing scope and changing urban environment, but it is not always completely re-aligned with the strategies of the city each time it is amended [8]. It tends to be easy to let plans fall on the metaphorical "back-burner" until they are out of date, or to allow the problem that directed the formation of the plan grow past the capabilities of the devised plan that was developed to solve it [3]. Both of these situations can be alleviated with the proper performance assessment not only at the end of the process but continuously through the process. This idea is discussed further in section 2.1.9.

2.1.8 Product & Process (Outputs)

It is not difficult to see this parallel, as it exists in almost every profession. When a plan set forth by an urban planning committee is commenced, it aims to make a change or implement something new. The change that is made (for better or for worse) is regarded as the output of this process, and the same is true of systems engineering.

2.1.9 Re-evaluation

An important feature not yet discussed is the iterative nature of systems engineering. Each step of the INCOSE process in Figure 2 has a leader to an undescriptive box labeled "re-evaluate." In the SE method, re-evaluate means a variety of things in a variety of contexts. In "state the problem" it is used to direct the thought process to determining if the problem is accurately defined. In "investigate alternatives" it would refer to both double checking each idea to determine if it was able to effectively address the problem as a whole and eliminating additional features that may not be necessary because they do not address the problem. In "integration" it would refer to re-evaluating the signals, energy, data, or materials that moved across each interface boundary. The re-evaluation stage means something different for each of the steps in this process but is important to keep the process and solution aligned with the problem it aims to address. This is a critical step that is often missing or not documented in the modern urban planning process. Most of the re-evaluation performed by the planning profession is executed only after deployment; when it is easy to asses if the outputs of the plan meet, exceed, or fall short of the desired outcome. While this is an effective method, it does not meet the preparatory and exacting nature that the SE method attempts to provide.

3 Results: Discussion & Validation

Now that we have built a framework to house the new theory of SE & UP (urban planning), we can address key points in each of the eight methodologies (from section 1.3) and use the SE methodology to reduce the number of disadvantages with each. To restate the claims, The SE & UP theory will:

a. provide a unified methodology for needs analysis in each of the three realms defined in section 1.1,
b. help recognize interactions and interfaces between these realms,
c. denote the benefits of defining the hierarchy of the city as a system,
d. and provide a reiterative structure that includes testing and evaluation to adapt to changes in the urban environment.

3.1 Claim A

As stated before, three main realms exist with which an urban planner is concerned: the physical, the economic, and the social. Each of these three will be separately discussed with respect to thorough needs analysis.

The physical realm stems from the traditional theory of comprehensive land use planning. It is characterized as focus on the shape, appearance, and layout of urban areas. This portion of urban planning is usually rather well-defined as there is an occupation under an urban planner known as an urban designer (which is rather familiar to the SE Perspective as there are specialized engineers under the leading systems engineer.) The main purpose and role of the urban designer is to strategically formulate the layout of physical features in a city. This may be roadways, buildings, parks, landmarks,

and more. The needs analysis for this is important, but rather straightforward. For example, if an intracity roadway is congested due to an influx of traffic, there is direct data that can be measured from the roadways that will help accurately develop the requirements for a project that will alleviate it. If the city were to set a goal of developing a unified appearance, the urban designer could develop architectural concepts and receive feedback about which one best fits the desired appearance of the city council. Attributes from the selected concepts could develop a list of more artistic concepts for the layout of new buildings. The physical realm is probably the least abstract of the three discussed, and also is the only one with a truly direct occupation underneath.

Economic possibilities for a city go hand-in-hand with the growth of a city. Often, these economic chances are brought about by advancements in technology with specific regard for transportation. Technological advancements are, by Kossiakoff, considered an input to the needs analysis process [15]. These technological advancements can help cities grow, as well as cause economic stagnation. For instance, the improved understanding of waterways and canals in the 1840s gave the ability for New York City to be connected with Western markets, helping that city grow economically [16]. On the contrary, this same canal-building technology also can cause the sudden decline in the economic well-being of a city. When the canals were built that enabled the opening of the St. Lawrence Seaway in 1960, there was no reason for west-bound ships to stop in Buffalo [17]. This industry was the livelihood of the city built strategically between lakes Ontario and Erie. Soon after the shipping industry collapsed in this city, the population began to decline. At Buffalo's Prime (as recorded by the 1950's Census) the city was home to over 580,000 inhabitants. Now, with the most recent population census in 2010, the city has declined to under 260,000 inhabitants, under half of what it was. While a change in planning methodology may not have been able to halt the decline of the shipping industry that Buffalo was known for, it could have accounted for such an event by investing in a different growing industry. It is crucial to understand how technological advances will affect the current city plan, and determining the requirements for a city to stay economically afloat in a world of constantly changing technology is equally crucial.

The other realm that urban planners are increasingly concerned with is that of social engagement of citizens. The initial comprehensive land use planning theory barely takes into account this factor. The social realm is more of a new-school methodology that is closely addressed in the advocative and radical planning theories. The radical planning methodology is frequently reduced to advocative planning theory due to the hierarchical nature of the government as well as the debatable effectiveness of the strategies used. The advocative planning theory is characterized as using input from citizens to develop the next generation of plans. These plans generally do not focus heavily on the economic or physical realms, but scrutinize the effect each plan will have on the population. This is an important consideration because you can satisfy the economic needs of a city but house a miserable population. One of the key examples of this is actually found in mid-1980's Cairo, Egypt [18]. The city was massive, housing over 9 million people at the time, and was quickly growing. The city was growing so fast in fact, that there was an incredible deficit in housing. The traditional family was disrupted by this housing crisis, and so-called "nuclear families" formed. Nuclear families are described in these conference proceedings as families living together, housing up to three generations, each with their own family. If there was a requirement analysis performed for the city with regards to the social realm, then there would have been heavy emphasis on building an abundance of housing developments.

It is the requirements analysis that shapes the resulting plan and determines the acceptable level of performance of city projects. The necessity of a needs analysis for all three realms is apparent, but how

will we consider a theory that maintains a strong methodology while still accepting input from the population? The SE method has the answer. The SE process focuses heavily on methodology and has developed a series of analyses that help lead to four types of requirements [15].

Types of Analyses	Types of Requirements
• Operations Analysis	• Operational Requirements
• Functional Analysis	• Functional Requirements
• Feasibility Definition	• Performance Requirements
• Needs Validation	• Physical Requirements

Applied to urban planning, each of these analyses would produce valuable insight into the state of the city, and would lead towards the development of the requirements above. The operational requirements would convey the overall nature of the plan and the changes in the city brought about by its implementation. The functional requirements will refer to a narrower list of what the plan would do and focus more on the tasks it would perform while in progress. The performance requirements will specify the extent to which the plan will alter the environment of the city (where the environment consists of the three realms of urban planning.) Lastly, the physical requirements will provide a synopsis of the physical realm of the plan, and should also contain constraints based in legislature, available capital, and the limitations of the community's availability to support the plan.

One of the benefits to the SE approach over any of the available planning theories is that is tailorable to the specific needs of the plan. Any necessary emphasis on the physical, economic, or social aspect of the city will become apparent if this process is applied correctly. The advantages of the comprehensive, advocative, and radical theories are combined and remain in this method, but the disadvantages of weak methodology have been eradicated.

3.2 Claim B

Within an urban plan that spans at least both physical and social/political realms, there is normally weak mention of mention of the predicted interactions that may exist across the finalized scope of the plan, and this is usually resolved by amending the plan as these unintended interactions arise [7]. This can be considered a waste of time and effort that could have been avoided if interactions were identified at the plan's inception. The amending effort should be considerably more focused on reacting to changes in the environment of the city with regard to the contexts discussed in section 3.1. Interfaces are another strong consideration of SE and should be transferred to UP. Committees should be tasked with finding each interface between the subsystems of a city to increase the likelihood of managing those interfaces correctly. This thought process is sometimes performed naturally during plan definition. For example, if a city was in the process of developing ideas for a new transportation system, and a subway was chosen, there needs to be an interface between the walkable city-scape and the train itself. This interface is commonly known as a subway station. This example also appears to be an engineered system but it falls directly in the scope of the planning committee, and thus needs to be a consideration for *at least* the physical realm of the city plan as well. These interfaces and interactions are seen between each of the three realms and can be predicted with enough effort to minimize the inadequacy of the plan. While the full extent of interactions between and across the three realms and subsystems of a city will not be derived in this paper, an example will be given to brief the reader in the type of interfaces and interactions they could expect to see during the use of the SE & UP theory.

Four possible interactions exist (three two-way, and one three-way) between the three realms, and each comes with a myriad of interfaces that will need managed by the agencies responsible for the fulfilment of the specific task within the plan.

The first interaction arises between the social and economic realms. We can use a relatively simple example to portray this relationship, with a case previously discussed. Buffalo thrived economically when the shipping industry was funneled through the city [17]. There was a wealth of jobs and businesses looking to hire employees, but this was soon changed and thus there was a lack of both jobs to satisfy the people, and economic income to the city. This is a rather direct relationship and is an easy relationship to generalize: if a municipality has the ability to create jobs by introducing an industry then both social well-being and economic prosperity will increase.

The second interaction deals with the economic and physical realms. Let's say the generalized municipality that had the ability to create jobs by welcoming an industry, was welcoming a manufacturing plant. The company who wants to build the plant is looking for a pretty large area. The city knows that the only area this large is near two neighborhoods, and the space that would satisfy the company is currently pre-allocated to a third neighborhood. The urban planning committee can start to characterize the impact of putting a factory on land that has already been assigned by viewing possible traffic changes due to an influx of commuters to the area, as well as the new land that may have to be developed to house new citizens. The committee would also need to look at the possibility of restricting the factory size to move it to land that was ordained for economic growth and already has the facilities for the treatment of the byproducts of this manufacturing process.

The third interaction materializes between the social realm and the physical realm. Relationships between the people and the material infrastructure of the city can not be avoided and should be predictable. Failing to predict this could reduce citizen comfort at the minimum. This relationship is demonstrated in a study conducted by Richard Fuller. Fuller recognized the growing city-based populations and wondered how greenspace influenced human perception of a city, where greenspace is a grassy (or similarly vegetated) area allocated "primarily for aesthetic or recreational activities" [19]. It was found that greenspaces with more biodiversity and the self-perceived well-being of citizens in that area. This is an important interaction between humans and the physical components of the city. This interaction appears to deal with the people themselves and the physical embodiment of the city, which is true, but not the full magnitude of the social realm. This realm also encompasses the political aspects of people within a city, as well as outside of it. Large scale political decisions can be made that directly influence the policies and projects that a city can undertake. For instance, the Federal Highway Administration has legislature that deals with the allowable consistent urban noise allowable in housing developments [19]. This must be taken into account when developing the plan, the closer a development is to a busy highway, the louder the noise. This must be taken into account when designing roadway paths, or while apportioning land for future neighborhood development.

The fourth interaction is a combination of all of the above. Consider a city that were to try to implement all the hypothetical plans discussed in this claim. We can take a look at the implications with regard to the simple interactions discussed above. A city is implementing a new manufacturing plant. Accounting for the (albeit hypothetical) interactions seen above, if the manufacturing plant was kept the same size and placed nearby the housing development areas, the city might see reduced "greenspace," an increase in economy and prosperity and a negative effect due to factors that make up social well-being (increase due to job opportunity, but a decrease due to removed greenspace and noise complaints) With the other possibility, the factory could be moved to the other site and they could

expect no change in greenspace, a lesser increase in job opportunity, and a lesser increase in economic prosperity, but a positive impact in social well-being. Granted, this is a vague oversimplification of the complex interactions seen within a city, but it is the interactions as defined by the SE method that could lead to the considerations that make an effective trade-off analysis.

The SE focus of creating an understanding of how segments of the city plan will interact with other parts captures the intent of the incremental planning theory. The advantages of the SE & UP theory over this theory is that (assuming a semi-experienced planning team is using this method) a majority of interactions and interfaces are defined and the committee does not need to wait for the unknown interactions to emerge.

3.3 Claim C

Note: This claim has the objective of identifying benefits to mapping the city as a hierarchy rather than actually mapping the city as a hierarchical system. The mapping process would be an entirely different research topic.

The hierarchy of an engineered system has significant benefits to that of the team's understanding of how the system works together. This hierarchy also gives a definite reference document that the committee can use to develop the possible impact of future changes to the system. When a subsystem or assembly is replaced in an engineered system, all of the parts, and components must be replaced as well [21]. This means that the hierarchy denotes exactly what will be replaced, and what functions will be removed. This is important to an urban planner, because it would be a quick way to asses the impact of removing, or adding a public transportation subsystem to the city. Another consideration is that new top-level policy changes will apply to the entire hierarchical chain underneath the intended target for the policy change. Understanding this change would help to create more articulate legislature and plans at the committee level because the unintended consequences would be recognized immediately.

Again, this claim tries to incorporate advantages or decrease disadvantages of the current planning theories listed in section 1.3. The two methods that apply to this are innovative planning and allocative planning. Incorporating the system architecture of a city would include the advantages of innovative planning because it would encourage a more self-guided approach to managing each of the subsystems and hopefully provide the managerial structure to accompany such an independent approach. It would also contribute to longer-term plans due to the static (for the most part) nature of a hierarchical system, thus decreasing the drawback of innovative planning: short-term plans. The benefits of allocative planning would also be improved due to the ability to detect if parts or components analogous to a city are missing, and can prevent poor distribution of resources.

3.4 Claim D

Arguably, the reiterative method of SE is one of its strongest assets. The INCOSE model outlines certain decision gates that allow for progression to the next task only if the previous stage is acceptable. These decision gates provide the team the ability to adapt to quickly changing urban environments while making sure each factor aligns with the overall goal, and making sure the overall goal still aligns with the city's needs. This recursive feature, continued from the discussion in section 2.1.9, addresses the last theory that has not yet been addressed thus far. This advantage comes from the middle-range planning theory. The middle-range planning theory works do simultaneously develop a detailed short-

term plan (1-5 years), a general long-term plan (20+ years), and a moderately informative mid-term plan (5-20 years). The iterative structure of the SE method allows for constant visitations to the plans of all lengths. At every iteration or gate, there is a validation of alignment for short-term needs and goals, mid-term objectives, and the long-term goal. This also solves the disadvantage of poor plan reactivity to changing urban conditions seen in all but the innovative, radical, and advocative planning theories without sacrificing the strong procedural methodology seen in the other strategies.

3.5 Hesitations

At this point, we have discussed the advantages the SE & UP method borrows from each of the planning theories, and the disadvantages of each that the SE & UP method has the capability to solve. An optimistic approach has been used to determine how the systems engineering method can be combined with the advantages of the urban planning theories, but we must now look at the hesitations of implementing such a method. First, cost is high in reiterative processes such as SE, especially when it comes to the requirements analysis [22]. Smaller municipalities may not be able to afford the in-depth requirements analysis needed for a successful SE process, and may need to stay their current strategies of predicting needs. Second, this method is also rather time-consuming. The innovative and radical methods of urban planning have the ability to react quickly to urban changes (referred to as "crisis situation planning methods" by Oner [7]), implementing new policy and projects quickly, and amending the implementations later as needed. This goes against most of the SE principles that this paper tried to incorporate into a solidary planning theory. In a case like this where a reactionary response is urgently required, another method might be necessary to use as a fallback. Lastly, Kossiakoff states that:

> "The systems engineer generally matures in the field after a technical undergraduate degree with work experience and a master of science degree in systems engineering, with an increasing responsibility of successively larger projects, eventually serving as the chief or lead systems engineer for a major systems or systems of systems development" [15].

The SE method takes experience and occupational insight no matter the field to which it is applied. The SE & UP method formulated in this paper undoubtedly requires a strong and experienced team for any municipality's plan to reach success.

4 Conclusions

It is no doubt that the SE method would be an *impactful* change if applied to urban planning. Originally, the question was whether or not it would be *beneficial* to the urban planning process. This started as a difficult question because there was not just one accepted method of planning, but rather eight. In practice, they were found to use some of these theories interchangeably causing confusion in methodology and procedure. The SE method discussed the ability to capture the advantages of most if not all of the theories as well as pose solutions to the problems each theory developed. This led to the SE & UP theory. This theory used SE knowledge, terms, and ideas to build a framework that can be developed to improve the urban planning strategies used today. While there were hesitations pertaining to process cost, long schedule, and experienced team members, it was found that the overall process would be adaptable to favor any theory's advantages without straying far from the strong methodology of the SE Process. Figure 4 below demonstrates two different approaches, each favoring combinations of the planning methods discussed in this paper.

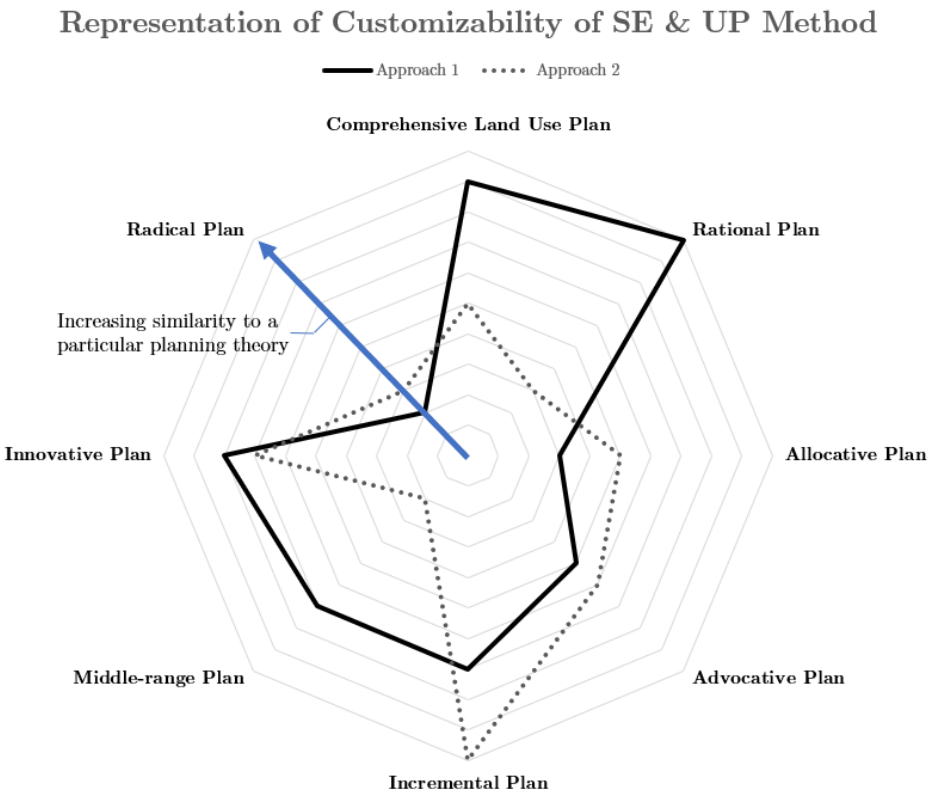

Figure 4 *- Graphic Portrayal of SE Flexibility to each of the 8 Urban Planning Theories (chart produced by author)*

This theory still has plenty of room to be further developed. Empirical testing should be completed to validate many of the assumptions of this theory, and case studies should be developed to study the implications of this method in real-world scenarios. Often, criticisms of planning theories are characterized by statements about a divide between the scientific process of planning and the real-world execution of planning [7]. The goal of future research would be to test the SE & UP method in practice and avoid these criticisms by bringing the results back to academia to advance the general knowledge of the field of urban planning.

BIBLIOGRAPHY

[1] S. S. Fainstein, "Urban Planning," Encyclopaedia Britannica, 2017. [Online]. Available: https://www.britannica.com/topic/urban-planning. [Accessed 26 10 2017].

[2] A. J. Scott, A World in Emergence : Cities and Regions in the 21st Century, University of California, Los Angeles: Edward Elgar Publishing, 2012.

[3] B. Bluestone, "Key Factors in Urban Economic Growth - What makes working cities work?," *Community Development: Federal Reserve Bank of Boston,* vol. 2014, no. Breif 3, pp. 2-21, May 2014.

[4] M. E. Smith, "The Teotihuacan Anomaly: The Historical Trajectory of Urban Design in Ancient Central Mexico," *Open Archeology,* vol. 3, no. 1, pp. 175 - 193, August 2017.

[5] M. E. Smith, "Form and Meaning in the Earliest Cities: A New Approach to Ancient Urban Planning," *Journal of Planning History,* vol. 6, no. 1, pp. 3-47, Februanry 2007.

[6] T. J. K. Jr., "The General Plan in the Urban Planning Process," *Council of Planning Librarians,* vol. July, no. 21, pp. 1-18, 1962.

[7] A. C. Oner, "An Espoused Continuum Theory of Planning Derived from the Analysis of the Planning Theories and the Planning Processes of the Fifty Major Planning Adgencies in the United States," University of Pittsburgh, Pittsburgh, 1980.

[8] E. de Leeuw and J. Simos, Healthy Cities: The Theory, Policy, and Practice of Value-Based Urban Planing, New York: Springer, 2017.

[9] International Council on Systems Engineering, "What is Systems Engineering?," INCOSE, 2017. [Online]. Available: http://www.incose.org/AboutSE/WhatIsSE. [Accessed 02 Nov 2017].

[10] J. Gomis and C. Turon, "Drawing the "Boundaries", the Start of an Urban Planning Project," *Geographia Technica,* vol. 12, no. 2, pp. 73-81, 2017.

[11] The City of Orlando, *The Growth Management Plan,* Orlando, FL: City Planning Division, 2012.

[12] S. Booth, "Updated TAZs on a Cloud Platform: Provide NFRMPO Communities a Clearer Picture," *AMERICAN PLANNING ASSOCIATION: Colorado Chapter,* p. Electronic, 29 April 2017.

[13] New York State Department of State, "Local Government Services," May Revised 2012. [Online]. Available: https://www.dos.ny.gov/lg/publications/Site_Development_Plan_Review.pdf. [Accessed 11 Nov 2017].

[14] Naval Air Warfare Center, "CDR: DoD Acquisition Guidebook - Section 4.2.13," April 2016. [Online]. Available: http://www.navair.navy.mil/nawctsd/Resources/Library/Acqguide/cdr.htm. [Accessed 04 Nov 2017].

[15] A. Kossiakoff, W. N. Sweet, S. J. Seymour and S. M. Biemer, Systems Engineering Principles and Practice, Hoboken, New Jersey (Simultaneously in Canada): Wiley, 2011.

[16] M. Polese, "Five Principles of Urban Economics," *Cities: Economy, Finance, and Budgets.,* vol. 5, no. Winter, p. {Not Listed; Online Reproduction}, 2013.

[17] C. LaChiusa, "The History of Buffalo: A Chronology," Buffalo: Architecture and History, 17 June 2001. [Online]. Available: http://buffaloah.com/h/1970.html. [Accessed 07 Nov 2017].

[18] M. el-Safty, "Social Aspects of Urban Planning," in *Architectural Transformations in the Islamic World*, Cairo, Egypt, 1985.

[19] R. A. Fuller, K. N. Irvine, P. Devine-Wright, P. H. Warren and K. J. Gaston, "Psychological benefits of greenspace increase with biodiversity," *Biology Letters,* vol. 3, no. 4, pp. 390-394, 2007.

[20] C. Corbisier, "PUBLIC ROADS - Living with Noise," Federal Highway Administration Research and Technology -Coordinating, Developing, and Delivering Highway Transportation Innovations, Jul 2003. [Online]. Available: https://www.fhwa.dot.gov/publications/publicroads/03jul/06.cfm. [Accessed 12 Nov 2017].

[21] INCOSE, SYSTEMS ENGINEERING HANDBOOK- A Guide for System Lifecycle Processes and Activities - V3, Wiley, 2006.

[22] J. O. Grady, System Requirements Analysis, Amsterdam, Netherlands: Elsevier, 2006.