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VALUE STREAM MAPPING OF INFORMATION FLOW IN INFRASTRUCTURE
PROJECTS

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Venkata Ramana Ari

**VALUE STREAM MAPPING OF INFORMATION FLOW IN
INFRASTRUCTURE PROJECTS**

VENKATA RAMANA ARI

ABSTRACT

Value Stream Mapping (VSM) is a tool for depicting the flow of material in a manufacturing process. This study demonstrates that value stream mapping can also be applied to the movement and processing of information in a non-manufacturing environment. Here, the handling of, and changes to, water project construction plans within the Cleveland Division of Water (DOW) are tracked using value stream mapping. The map identifies opportunities for the Division of Water to streamline its processes and ensure that accurate information about project construction reaches its primary database in a timely fashion.

Currently it takes about 19.1 weeks from the time a project is proposed to the time the construction may begin. The value stream map shows that 17 weeks of this time consists of non-value added activity such as backlogs and waiting. A second issue of concern to the DOW is receiving the changes made to the original project plans. It is common for crews to deviate from plan to accommodate unexpected conditions found at a construction site. These changes must be communicated back to the Division of Water.

Using Lean tools both value-added and non-value added activities on the value stream map can be identified. The future state map shows how the process might be improved after changes are made to the process. The challenge lies in organizing the information in the VSM to remove or reduce the non-value added steps. With the

recommendations made to the Division of Water, the time from project proposal to the construction may feasibly be reduced from 19.1 weeks to 12.1 weeks. Similarly the bottleneck in the flow of the updated project information is identified. It is recommended that the bottleneck be removed as its value is negligible.

There are some distinct differences between the office processes and manufacturing processes. Unlike production systems, information flows can be loosely structured and use informal scheduling, making it difficult to identify and map their values streams. However, companies can apply value stream mapping tool to office processes in the same way they use it in manufacturing.

TABLE OF CONTENTS

	Page
ABSTRACT.....	iv
LIST OF TABLES.....	viii
LIST OF FIGURES.....	ix
CHAPTERS	
I INTRODUCTION.....	1
I.1 History of Lean Manufacturing.....	2
I.2 Lean outside Manufacturing.....	4
I.3 Value Stream Mapping.....	10
II BACKGROUND OF THE CLEVELAND DIVISION OF WATER.....	13
II.1 Problem Statement and Proposed Solution.....	13
II.2 Background about Cleveland Division of Water.....	15
II.3 Information Flow in a Project.....	19
III CURRENT STATE MAP.....	21
III.1 Procedures.....	21
III.2 Current State Information Flow.....	22
III.3 Proposal-to-Construction Time.....	30
III.4 As-builts from contractor to GIS database.....	32
IV FUTURE STATE MAP.....	34
IV.1 Proposal-to-Construction Recommendations.....	35
IV.2 As-Builts-to-GIS Recommendations.....	38
IV.3 Future state map.....	40

IV.4	Other Project Classifications.....	43
V.	DISCUSSION AND CONCLUSIONS.....	46
	REFERENCES.....	49
	APPENDIX.....	52

LIST OF TABLES

Table	Page
I. Forms of Wastes in Government Organizations.....	6
II. Details of Non-Value Added Times in the Current State, Water Main Replacement Project.....	34
III. Key Differences between Water Main Replacement and Other DOW Projects.....	43
IV. Times for Different Project Classifications.....	44

LIST OF FIGURES

Figure	Page
1. DOW Organization Chart	16
2. Water main replacement project, Current State.....	23
3. Water main replacement project, Proposal-to-Construction, Current State, Timeline.....	31
4. Water main replacement project, As-Builts to GIS, Current State, Timeline.....	33
5. Water main replacement project, Proposal-to-Construction, Future State, Timeline.....	37
6. Water main replacement project, As-Builts to GIS, Future State, Timeline.....	39
7. Water main replacement project, Future State.....	41
8. Sewer project, Current State Map.....	53
9. Sewer project, Proposal-to-Construction, Current State, Timeline.....	55
10. Sewer project, As-Builts to GIS, Current State, Timeline.....	56
11. Sewer project, Proposal-to-Construction, Future State, Timeline.....	57
12. Sewer project, As-Builts to GIS, Future State, Timeline.....	58
13. Sewer project, Future State Map.....	59
14. Road widening & road reconstruction Project, Current State Map.....	61
15. Road widening & road reconstruction Project, Proposal-to-Construction, Current State, Timeline.....	63
16. Road widening & road reconstruction Project, As-Builts to GIS, Current State, Timeline.....	64

17. Road widening & road reconstruction Project, Proposal-to-Construction, Future State, Timeline.....	65
18. Road widening & road reconstruction Project, As-Builts to GIS, Future State, Timeline.....	66
19. Road widening & road reconstruction Project, Future State Map.....	67
20. Freeway, bridge and utility Project, Current State Map.....	69
21. Freeway, bridge and utility Project, Proposal-to-Construction, Current State, Timeline.....	71
22. Freeway, bridge and utility Project, As-Builts to GIS, Current State, Timeline...	72
23. Freeway, bridge and utility Project, Proposal-to-Construction, Future State, Timeline.....	73
24. Freeway, bridge and utility Project, As-Builts to GIS, Future State, Timeline....	74
25. Freeway, bridge and utility Project, Future State Map.....	75
26. Distribution main new installations and water main extensions Project, Current State Map.....	77
27. Distribution main new installations and water main extensions Project, Proposal-to-Construction, Current State, Timeline.....	79
28. Distribution main new installations and water main extensions Project, As-Builts to GIS, Current State, Timeline.....	80
29. Distribution main new installations and water main extensions Project, Proposal-to-Construction, Future State, Timeline.....	81
30. Distribution main new installations and water main extensions Project, As-Builts to GIS, Future State, Timeline.....	82

31. Distribution main new installations and water main extensions Project, Future State Map.....	83
32. Cleaning and lining Project, Current State Map.....	85
33. Cleaning and lining Project, Proposal-to-Construction, Current State, Timeline.....	87
34. Cleaning and lining Project, As-Builts to GIS, Current State, Timeline.....	88
35. Cleaning and lining Project, Proposal-to-Construction, Future State, Timeline.....	89
36. Cleaning and lining Project, As-Builts to GIS, Future State, Timeline.....	90
37. Cleaning and lining Project, Future State Map.....	91

CHAPTER I

INTRODUCTION

This chapter explores the history of Lean Manufacturing and how Lean can be implemented outside manufacturing. It will show how Lean is used in service and governmental organization, and present relevant case studies. Finally, it will introduce value stream mapping.

The term Lean thinking, or Lean production, was first used in the book by James P. Womack and Daniel T. Jones, *“The Machine that Changed the World”* [1]. Lean Manufacturing is a philosophical way of thinking, and has a basic goal of satisfying the customer through on time delivery and high quality products by simply eliminating waste. The entire lean philosophy is not as simple to implement as the definition might suggest. There are a number elements involved to make the philosophy work as a system. Perhaps a more understandable is the definition given by “John Shook:”. *“A manufacturing philosophy that shortens the time line between the customer order and the shipment by eliminating waste”* [2]. This means that one builds what the customer orders as soon as possible after the order, and that the total lead time between order and delivery is as short as possible.

I.1 History of Lean Manufacturing

Many people understand that lean manufacturing concepts and practices were developed for the Toyota manufacturing system. While this is correct, Lean manufacturing's history goes beyond this. Lean manufacturing concepts were used in other manufacturing systems before Toyota [3]. In 1104, the Venetian navy standardized the design for building warships using interchangeable parts. By 1574, the Venetian practices were so advanced that King Henry III of France was invited to watch the construction of a warship in a continuous flow. In 1765, French general Jean-Baptiste De Gribeauval had grasped the significance of standardized designs and interchangeable parts to facilitate battlefield repairs. By 1807 Marc Brunel in England had devised equipment for making simple wooden items like rope blocks for the Royal Navy. Twenty-two machines produced identical items in process sequence one at a time. By the 1822, Thomas Blanchard at the Springfield Armoury in the U.S had devised a set of a 14 machines and laid them out in a cellular arrangement [4]. The Ford motor company used Lean manufacturing concepts to manufacture the Model T automobile in early 1914. Henry Ford's ideas about continuous assembly lines and flow are considered very important concepts of Lean manufacturing today. Ford's production system eventually fell apart due to inherent problems in the system: of poor attitude of management towards the workers, and the inflexibility of Ford's system.

The next step of this manufacturing revolution occurred in Japan with the Toyoda family, when they shifted from textile equipment manufacturing to automobile manufacturing. In the late 1940's, Japan's industry had collapsed and its economy was

badly affected by World War II. In addition, Japanese manufacturers faced the problems of limited raw materials, labor unrest, and limited availability of capital. Japanese automobile companies could not compete with the already-existing companies in the West. Companies like Ford simply overwhelmed and out-produced smaller manufacturers like Toyota, which could not compete in the global market. Japanese manufacturers had to produce to their domestic markets, which were very diversified and small.

Challenged by these demands, Toyota assigned Taichii Ohno the task of engineering a system that could compete in these conditions. Ohno, with his colleague Shingo, spent the next three decades creating the Toyota Production System (TPS). The roots of this system were clearly linked to the Ford's system, as all managers in Toyota were said to have learned the Ford's system. They did not simply copy Ford's system, though. Instead, they clearly understood the advantages and disadvantages of Ford's system. Toyota's manufacturing method was further influenced by the Quality movements in the United States, especially the thinking of people after 1940, such as Juran and Deming.

From the 1940's through the 1970's, the Toyota Production System (TPS) was developed. By this time TPS was doing very well. During 1974, Japan faced economic problems from the oil crisis, which led to many Japanese companies operating at a net loss [5]. Toyota's success continued even in this period. This led many Japanese manufacturers to explore TPS as a solution to their problems. TPS started gaining popularity within Japan.

U.S. manufacturers began wondering about the growth of the Japanese industry. Norman Bodek was the first to publish the work of Ohno and Shingo in English. It gave American manufacturers awareness of Lean Manufacturing. Since then, Lean has become a buzzword in manufacturing. By the mid 1990's, many U.S. manufacturers were using this system to good effect. Today, Lean manufacturing is reaching the next step in its development. Lean manufacturers have now become Lean enterprises, which incorporate the entire supply chain. This includes suppliers, customers, distributors, and other stakeholders. Lean enterprise concepts are focused on all the people in the supply chain to get the best possible value from the collective effort.

I.2 Lean outside manufacturing

Lean manufacturing is a management philosophy focusing on reduction of the seven wastes in manufactured products-overproduction, waiting time, transportation, processing, inventory, motion and scrap. By eliminating waste, quality is improved, and production time and costs are reduced [6]. Lean has reduced inventories for manufacturers, improved knowledge management and decreased lead times for customers in an automotive industry [7]. Some of the cases where Lean techniques used are in ASMC in Dresden, Germany where they used it in the chipmaking operations. The Lean implementation reduced the lot travel distance from 925 to 363 meters; lead time variability from 2.86 to .83 days, and; lead time from 4.21 to 2.64 days [8]. Vibco Vibrators Inc. in Wyoming used Lean techniques and decreased their setup time for machines from 2 hours to 10 min [9].

Many companies have considered a Lean transformation to be limited to the manufacturing floor. One simple reason for such belief is an inability to differentiate

value from waste, and difficulty in implementing improvements, in administrative areas. In the initial stages of the implementation of Lean, many companies achieved remarkable improvement on the shop floor, but they neglected important office processes from the value stream map. By not including office processes, companies failed to see the total picture of the enterprise and thus could not effectively eliminate the waste present in the non-production areas [10]. Sometimes many companies neglect to look the actual causes of waste that are present in support processes for the shop floor. If the support processes are not considered, then opportunities for improvement remain, both on and off the shop floor. The ignorance of people in capturing the information typically creates twice the waste in the office than on the shop floor. Moreover the waste produced by office processes hamper the growth of companies.

Form of waste	Office Examples
1.Overproducing Producing more, sooner, or faster than is required by the next process	Printing paperwork out before it is really needed, purchasing items before they are needed, processing paperwork before the next person is ready for it.
2.Inventory Any form of batch processing	Filled in-boxes (electronic and paper), office supplies, sale literature, batch processing transactions and reports.
3.Waiting	System downtime, system response time, approvals from others, information from customers.
4.Extra processing	Re-entering data, extra copies, unnecessary or excessive reports, transactions, cost accounting, expecting, labor reporting, budget processes, travel expense reporting, month-end closing activities.
5.Correction Any form of defects	Order entry errors, design errors and engineering change orders, invoice errors, employee turnover.
6.Excess Motion Movement of people	Walking to and from a copier, central filing, fax machine, other offices.
7.Transportation Movement of paperwork	Excessive email attachments, multiple hand-offs, multiple approvals.
8.Underutilized People	Limited employee authority and responsibility for basic tasks, management command and control, inadequate business tools available.

Table I: Forms of Wastes in Government Organizations, from [10], page 17

Today the most important development in Lean manufacturing is the Lean enterprise concept. It reaches customers, suppliers and other parties in the process of value creation. The aim is to create value and eliminate waste not only within the organization but also throughout the supply chain. Suppliers are also very important in the Lean enterprise. In many industries more than half of the cost of manufacturing is in the raw materials. Every improvement a supplier can make will add to the value a company can deliver to its customer. It is very important that a manufacturer has a base of suppliers who can be trusted for their cost, quality, and delivery. They are a very valuable part of the process and even more important in achieving the goals of a Lean enterprise. In today's world manufacturers can do very little on their own in creating value. Each and every activity is interconnected very closely. Every part of the supply chain must improve simultaneously in order to deliver superior value to the end customer.

Lean may also be applied to service operations that are not concerned with the manufacturing of "hard" products. Lean principles are now being applied to call center services, restaurants, hotels, health care, higher education, software development, and public and professional services. These applications might not be necessarily repetitive, where "*takt*" time is not applicable, and where task times may be both long and variable. Generally these implementations follow similar paths to those in manufacturing settings, making use of the same tools and techniques. However there can be many significant distinctions.

In one case study, Lean was applied in a hospital environment. ThedaCare's Radiation Oncology department, based in northeast Wisconsin, identified patient waiting

time as the largest waste. The process from referral to treatment often took several days. The vice president of the Oncology department developed a value stream map (VSM) of all processes provided in a service line. The VSM revealed that many of the procedures did not improve value of health care being provided to their patients. The vice president led a team to correct these mistakes. One result is that ThedaCare's flow time from referral to treatment is reduced from 23 days to 8 days [11]. In another example, 28 hospitals in Pittsburgh applied the Lean philosophy towards care from 2001 to 2006. They reduced the number of patients arriving without lab results at operating room, achieved a 63% reduction in central intravenous line infections, and eliminated patient deaths from these infections [12]. Another case where Lean used in a hospital environment is at Spencer Hospital, in northwest Iowa. Lean is used for streamlining the process of admitting mental health patients. As a result they reduced average cycle time by 24% [13].

The term, "Lean Government", is generally used in United States and Canada, but it is increasingly heard in international public administration circles to describe an evidence-based process for the state to identify more efficient and value added methods to provide needed government services. As more government services are delivered electronically, Lean Government initiatives are commonly applications of Lean Information Technology (IT). The practice of value stream mapping is used to analyze administrative processes. The results are used to design technology use, task completion, and staffing patterns to meet identified needs.

There are many of steps involved in an office process. Those steps can be either value-added steps or non-value-added steps, but some non-value-added steps are

necessary for the support of the business. A person planning to implement Lean techniques in the office should know how to reduce the non-value-added-steps, as these consume time, money and resources without resulting in benefits. There are several types of wastes in office processes, shown in Table I. Once identified, then these can be eliminated for optimum performance. In addition to Ohno's seven wastes, some consider an underutilized person as an eighth waste, as his mental, creative and physical abilities are not fully employed.

One example where Lean Government practices have been implemented includes the Iowa state government. It has adopted Lean initiatives in their 81th general assembly. In 2004, the Department of Cultural Affairs reduced their number of steps from 142 to 74, delays from 30 to 8, and hand offs from 29 to 11. The Department of Natural Resources, in 2007, reduced their number of steps from 258 to 139, handoffs from 104 to 40, and decisions from 27 to 12 [14]. In another case, the Connecticut Department of Labor adopted the philosophy, principles, and practices of Lean Manufacturing to its government environment in 1999. They used the lean for the empowerment of line staff, and by doing so they eliminated 119 steps and 1181 cycle-time hours [15]. Lean was initially applied to the Chicago Transit Authority in the 103rd Street garage. By applying Lean they sequenced maintenance tasks to reduce walking distance from 3000 feet to 1200 around a 40-foot bus, and shortened lead time for warranty repair decisions [16]. In addition, Lean was applied in the Letterkenny Army Depot in Chambersberg, PA, which was in danger of being closed in 2005. By applying lean techniques they reduced solid waste disposal by 58% through recycling, and reduced hazardous chemical use by 75%. Ultimately, Letterkenny won two Shingo prizes and remains active today [17, 18].

I.3 Value Stream Mapping

This research study uses value stream mapping (VSM). VSM is the discipline of mapping the material and information flows that are required to coordinate the activities performed by manufacturers, suppliers, and distributors, to deliver products to the customers [19]. Sometimes, it is defined as a collection of all actions value-added and non-value added that are required to bring a product or a group of similar products from the raw material to the customer. VSM helps to identify all types of waste in the value stream and target specific areas for improvement [20]. It helps to see the big picture and improve the whole flow. Some firms that followed different Lean tools like JIT, 5S, and TPM, felt that there is a need to understand the entire system in order to gain maximum benefits from lean [21].

VSM is a pencil-and-paper tool, which is created using a standard set of icons [20]. VSM looks at the full, end-to-end process. It helps map visually how information and materials flow through all of the activities that occur from the time an order is placed, to the time the product or service is delivered. A VSM starts with a customer communicating an order, and ends when the product or service is delivered to the customer [22, 23].

Generally a VSM tool contains both a current state map and, one or more future state maps that represent progressive improvements to the current state map. Before drawing a current state map, a particular product or product family must be chosen as the target for improvement. The current state map is the beginning point of the enterprise transformation: it represents the baseline condition of how the company organizes and progresses work. The map itself solves no problems; rather, its purpose is to point to problems in the company's work streams [22]. The current state map is essentially a

snapshot capturing how things are currently being done. This is accomplished by following the selected product from beginning to end, observing every process. The second aspect of the current state map is the information flow that shows how each process knows what, and how much, to make. The information flow is drawn on the upper portion of the map, left to right. Travel time is the time taken for the information to reach from one process step to another, and is shown on the information arrows. Every process box there will display both value-added time and non-value-added time for the given step. The value-added time represents the sum of the processing times for each process, while non-value-added time is the time that is taken for waiting and backlogs. After the completion of the map a timeline is drawn below, showing both the value added time and non-value added time for the complete process [24, 21]. Figure 2 shows a representative VSM.

The final step in VSM is to create a future state map, which is a picture of how the system can look after the wastes have been removed. The purpose of value stream mapping is to highlight target areas for improvement. The future state map is an implementation plan that details which Lean tools are needed to eliminate waste in the value stream. Creating a future state map is done by answering a set of questions on issues related to efficiency, and on technical implementation related to the use of Lean tools. This map then becomes the basis for making the necessary changes to the system [24, 21]. A similar method is used for drawing the future state map as with the current state map.

VSM has been used in aircraft manufacturing. Current and future state maps were developed with the objective of reducing lead time, according to customer requirements.

Implementation of a future state map attained lead time reduction from 64 to 55 days [21]. VSM has also been applied to steel manufacturing. Results obtained after implementing future state maps are lead time, a reduction in from 65 days to 11.5 days, and cycle time from 7262 second to 6902 seconds [14]. Third, The Connecticut Department of Labor used Lean in the state insurance program. By applying value stream mapping they eliminated 18 steps in the process and saved about \$13,200 per year in material costs [14]. Finally, Partsco, a distributor of electronic, electrical and mechanical components mapped their activities between the firm and its suppliers. In a short time the company was able to reduce the lead-time from 8 to 7 days [21].

CHAPTER II

BACKGROUND OF THE CLEVELAND DIVISION OF WATER

Here, the problem statement and proposed solution are presented. Explained background about the DOW. Showed all the different departments under DOW and also explained their responsibilities. Finally showed six different types of water projects undertaken by DOW.

II.1 Problem Statement and Proposed Solution

The Cleveland Division of Water (DOW) is not getting prompt feedback about the deviations from planned work on various water projects. Incorrect or incomplete information can adversely affect future infrastructure projects; work crews will either spend time searching for, or will accidentally encounter, mislocated water mains. Both conditions will add time and expense to a project. Second, there is a delay in the beginning of the project construction after it is proposed because of backlogs present in each step in the project. By applying Value Stream Mapping, to the flow of information

in DOW projects; the sources of backlog and delay that are present in the current state can be rectified.

The Distribution System Engineering Services Department (DSES) within the DOW undertakes number of construction projects. This study deals with the six classifications of projects, listed here.

1. Water main replacement, relocation, lowering projects
2. Sewer projects
3. Road widening and road reconstruction projects
4. Freeway, bridge and utility projects
5. Distribution main new installations and water main extensions projects
6. Cleaning and lining projects

These projects are described in detail in section II.2

When a contractor completes water projects, they should submit as-builts to the Geographic Information System (GIS) department. As-builts are drawings depicting all the modifications to the construction, showing how the construction was actually built as opposed to how it was designed. As-builts also include information about the dates and material type used in construction. Right now, the as-builts are not always submitted on a timely basis and some are not submitted at all. When as-builts are not updated promptly in the GIS, it can result in undue costs and delays to contractors, property owners, and the DOW. Future projects will be delayed because locations of water mains and other fixtures are not correctly identified on DOW maps.

In order to solve this problem, Lean tools such as Value Stream Mapping are applied. The VSM will have a current state map, which shows the present situation for

each project and how information flows from one department to another. The current state map is developed through personal observation of activities in a project. Seeing each project gives the researcher an understanding of how information moves from one department to another. Understanding the present situation, where bottlenecks are and allows for the development of a future state map, which shows how a process can be improved. The future state map leads to recommendations for each project, and describes their benefits in reducing the total lead time and travel time.

II.2 Background of the Cleveland Division of Water

The City of Cleveland's Division of Water was founded in 1857. The Division of Water is a major regional utility which supplies water to more than 1.5 million residents in Cuyahoga, Medina, Summit, Geauga, and Lake Counties. The Division of Water services approximately 400,000 retail accounts in the City of Cleveland and 72 suburbs. In addition, the Division sells water on a wholesale basis to five other suburban communities on a continuous basis, and to four other communities on an emergency or temporary basis. DOW is now the 10th largest water purveyor in the country.

The Cleveland water system consists of nine service districts (zones) that cover an area of 620 square miles and include 4600 miles of water mains. Each district operates under different pressure zones. Pressure zones are regional water delivery grids that are maintained at different reference pressures, according to the geography and water tower locations. Within each district, pressure regulated sub-zones may exist. In addition, DOW has service agreements to supply water to new developing areas, which might require creating a new service district.

There are six main departments in DOW. These are depicted in Figure 1, along with the hierarchy within the Engineering Department.

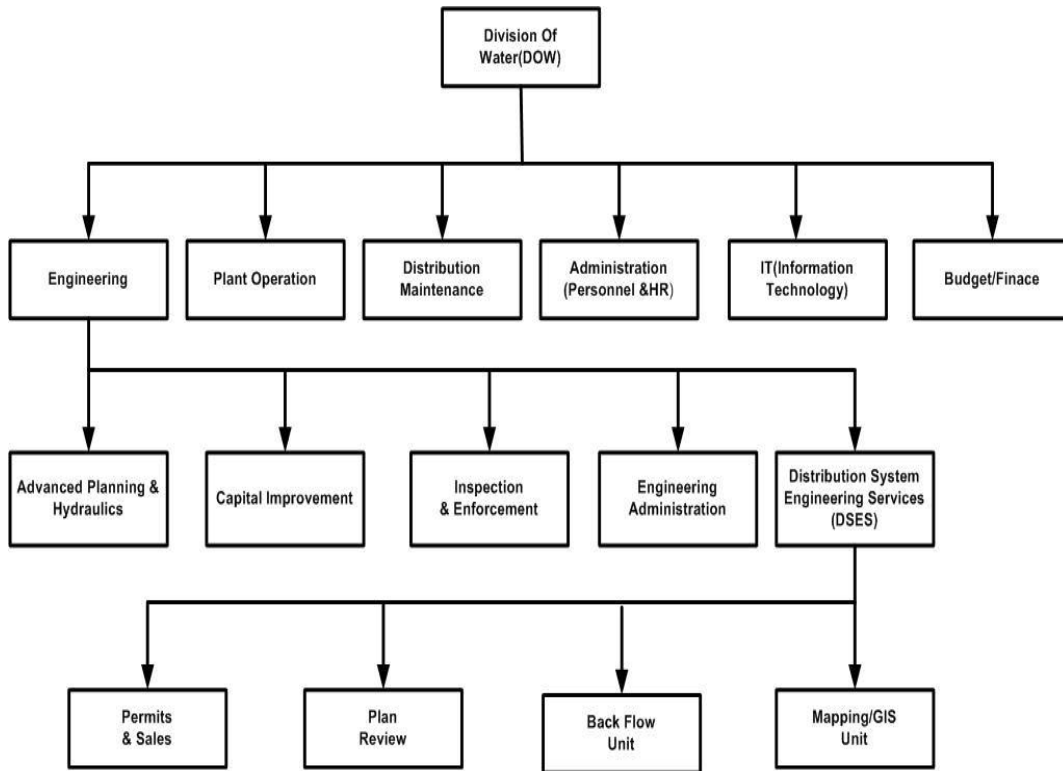


Figure 1: DOW Organization Chart

This study focuses on the Distribution System Engineering Services department (DSES), which is one of the departments under the Engineering. Guy Singer is the head of this department. The main responsibility of this department is to provide engineering consulting and assistance to developers, engineers, contractors, property owners and other DOW customers in the areas of project planning, standards, details, records, policies, rules and guidelines.

The responsibilities of the four departments within DSES are as follows.

Permits & Sales (P&S): Responsible for permitting all new water services, including temporary and permanent water services; and for the sale of other DOW services such as disinfection, service line taps and meter sales.

Plan Review (PR): Responsible for ensuring that all construction projects within DOW's service area are built to national and DOW standards.

Back Flow Unit: Responsible for ensuring customers in the DOW service area have a proper, functioning backflow prevention device and overseeing the annual testing process. A back flow device helps in preventing the water to flow back to the water main connection or the water tank.

Mapping/GIS (Geographic Information system) Unit: Responsible for documenting all changes in the distribution system such as pipes, valves and hydrants.

In a typical year, DOW undertakes about 1000 projects. At any given time 50 projects are active. Projects are classified by DOW in one of six categories.

Water Main Replacement, Relocation, Lowering Projects: All these projects are undertaken by the City of Cleveland, Division of Engineering and Construction, Division of Water, or other agencies or communities. A water main replacement project begins when the DOW determines that there is excessive leakage in a section of the water main. Relocations typically occur as part of road construction projects, when a road is being reconfigured. A lowering project occurs when there is a conflict with the existing main and other utility installations. In a lowering project, the water main is moved deeper into

the ground. All three of these projects involve excavation of a length of main pipe, removal of the old pipe, installation of the new pipe, flushing and sanitizing, and reconnection to the water grid.

Sewer Projects: Sewer projects are typically undertaken by the City of Cleveland, Division of Water Pollution Control, Northeast Ohio Regional Sewer District (NEORS) and other sewer districts/communities, or the Ohio Department Of Transportation (ODOT) for various reasons. These reasons include failing sewers, capacity issues and flooding, utility conflicts, and road relocations.

Road Widening and Road Reconstruction projects: Some road projects can affect the underground water infrastructure. Road projects can be administrated by the Cleveland's Division of Engineering and Construction within Cleveland, other municipalities, or ODOT. Widening projects add to a road's traffic-carrying capacity, while reconstruction projects repair or replace the road's surface.

Freeway, Bridge, and Utility projects: Conceptually, these projects are similar to road widening projects. However, they span multiple agencies and are therefore classified differently within the DOW. Bridge projects are undertaken when there is a failing bridge or improve the transportation on the bridge. Freeway projects are undertaken by ODOT or Ohio Turnpike Commission. These projects are undertaken when the freeways have deteriorated, or when there is a need to add lanes. Various utility companies undertake projects to repair or upgrade existing utilities.

Distribution main new installations and water main extensions projects: These projects are commissioned by private developers and property owners to supply water for new construction and developments.

Cleaning and Lining projects: Cleaning and lining projects are performed to rehabilitate old and corroded water mains by cleaning the interior of the main. Cleaning and lining is a process that removes calcium deposits from the inside surface of cast iron pipes, and doesn't require excavation. After cleaning, the inside surface of the main is coated with cement mortar. Cleaning and lining improves the flow capacity and water quality.

II.3 Information Flow in a Project

The Cleveland Division of Water is not getting prompt feedback about the deviations from planned work on various water projects. Incorrect or incomplete information can adversely affect future infrastructure project. Therefore, there is a need to understand why the DOW is not getting prompt feedback about these deviations. In order to gain this understanding, it is necessary to observe the present procedures used in the various projects that are undertaken by the DOW. Value Stream Mapping is a tool that helps to picture the current state of information flow in each project. From it, the actual bottlenecks and gaps can be located, and the proper solutions to overcome those defects identified.

For water projects, the customer is typically an agency such as a suburb, or ODOT. When a customer plans a water project, he will hire an engineering firm to develop project plans. When completed the engineering firm sends hard copies (drawing) to the Plan Review (PR) department which is part of DSES. PR approves the plans if they meet national and DOW construction standards. After the plans are approved, then the administrating agency will hold a bid to select the contractor at DOW. As much as possible, the winning contractor will construct the project according to plan.

Sometimes, there will be unanticipated situations, such as one utility conflicting with another, or details missed by the engineering firm while developing the drawing for the project. In these situations, the contractor will reroute the project away from other utility, and will modify the construction project accordingly. These changes, which should be marked on the hard copies, are called as-builts. After the project construction is completed, the contractor needs to submit the as-builts to the DOW mapping/GIS unit, which is located in the DOW main office in downtown Cleveland.

After receiving the as-builts, the mapping unit will scan them, and send the scanned copy electronically in a .TIF format to the GIS department. The mapping unit will then file the as-builts hard copy for future reference. Meanwhile, the GIS department will update the GIS database with the information from the as-builts.

In summary, if a customer needs any water service from the DOW, then he needs to hire an engineering firm to create project drawings. The engineering firm will send the plans to Plan Review. After a contractor is selected, the contractor will start construction. Field modifications to the plans (“as-builts”) are noted on the original drawings, and cleaned up after construction. The as-builts are returned to the DOW for updating the GIS database.

CHAPTER III

CURRENT STATE MAP

Chapter III details the procedures for handling information in a water main replacement project. It shows the current state map of the project and the associated timeline. The current state map is used to identify the bottlenecks between project proposal and construction, and in receiving the as-builts.

III.1 Procedures

This study uses Value Stream Mapping to find the underlying reasons for the delay in the construction of the project after it is proposed, and for as-builts not reaching the DOW from contractors on timely basis. To find those reasons, it necessary to understand the actual process flows in DOW projects. Guy Singer, the head of DSES, explained each individual project in detail, and had provided the author with a single process flow chart encompassing all six types of projects managed by the DOW. To understand the actual process, the author followed one project, observing every step that occurs in the handling of project information. The selected project is a 1000-foot water main replacement project being done in Cleveland on East 131st Street, stretching from Northfield Road to Perkins Road, and serving 50 residential customers. All the steps

involved in this project, from the start until the end, were observed. This involved interviewing DOW staff, and managers, and external contractors. This project was selected as a representative project that includes process elements found in other project types. With this information, a current state map of the water main replacement procedures can be developed.

III.2 Current State Information Flow

The Figure 2 shows the current state map of a water main replacement, relocation and lowering project. The current state map follows a hypothetical water main replacement project, based on the East 131st Street, stretching from Northfield Road to Perkins Road. This “typical” project involves replacing 1000 feet of water main serving 50 residential customers and is based on observations on the selected project.

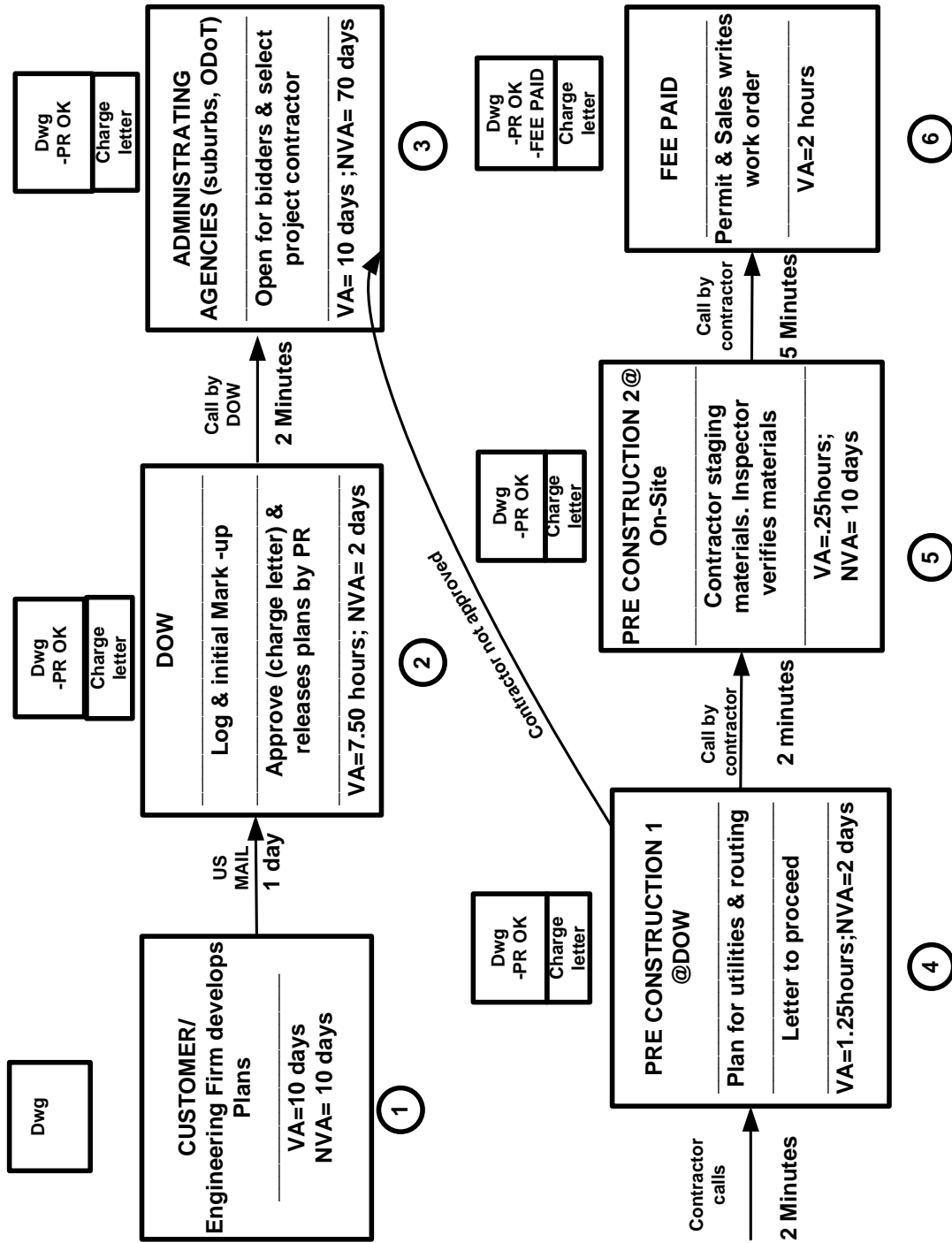
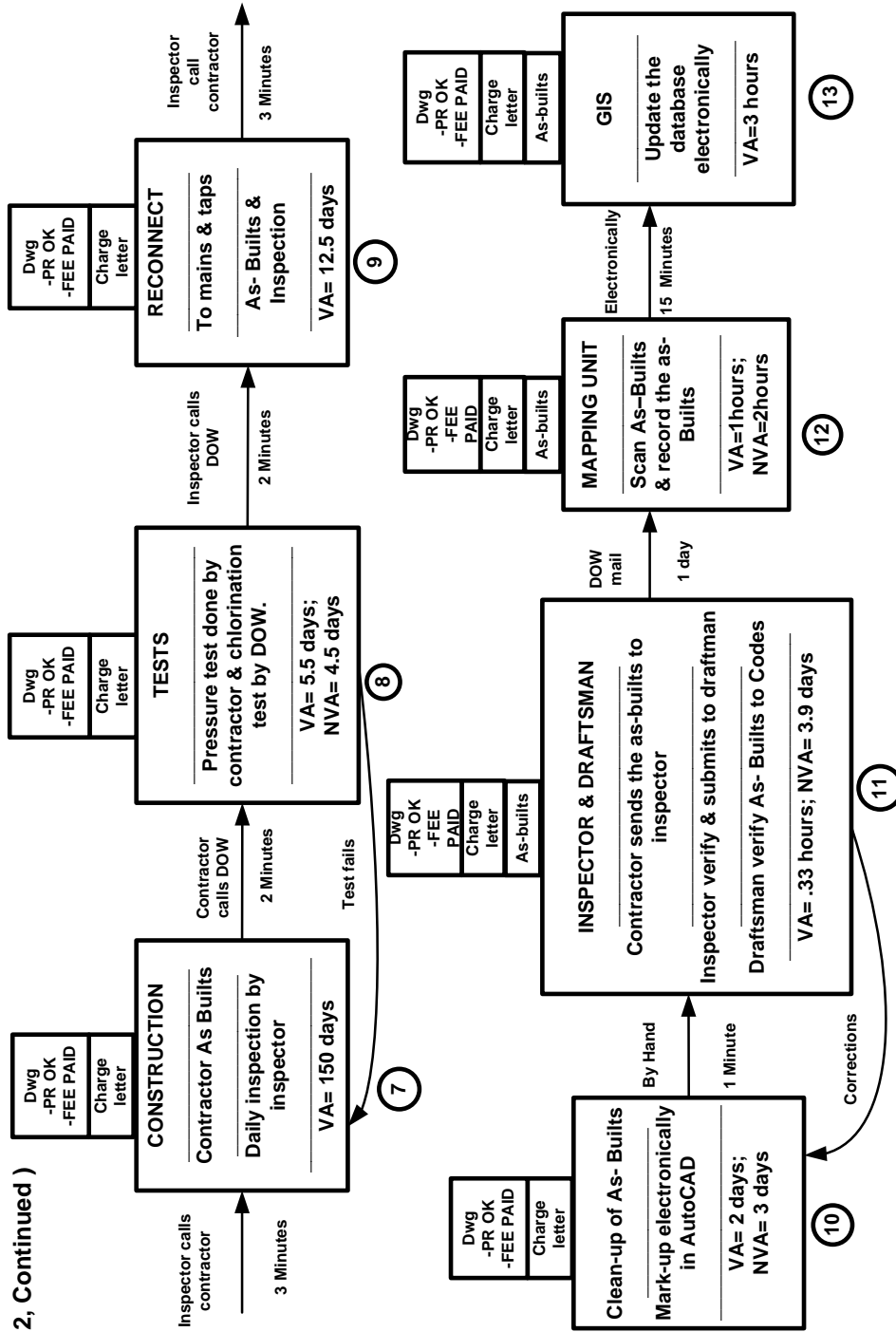


Fig 2: Water Main Replacement Project, Current State Map

(Figure 2, Continued)



The following paragraphs detail the process steps depicted in the value stream map Fig.

2. The block numbers refer to the process steps in the VSM.

Block 1. For this example, the customer is a suburb, which employs an engineering firm to develop plans for a proposed water main replacement project. The engineering firm submits hard copies of the project drawings to the Plan Review (PR) department located at the DOW office in downtown Cleveland, by U.S. mail.

It will take the engineering firm at least two weeks to prepare drawings for a project of this scope. In, addition, there is a backlog of about 80 working hours. This backlog occurs because a number of projects are occurring simultaneously, and is considered non-value added time (NVA). After developing the plans, the engineering firm sends them to the DOW by U.S. mail, which takes about one business day.

Block 2. PR receives the hard copies from the engineering firm, and log the plan in their database. After logging the details, they check whether the proposal meet construction standards. If the standards are not met, then PR does mark-ups on the hard copies and returns them to the engineering firm by U.S. mail. If the proposed project is approved, then PR will generate a charge letter. The charge letter details the fee that will be charged to the customer for DOW services. PR releases the drawing plans and sends them to the Engineering Field Service Office (EFSO). EFSO, located in the Cleveland suburb of Parma, is one branch of the DOW.

It takes PR 30 minutes to log the plans, 4 hours to complete mark-ups, two hours to generate a charge letter, and one hour to release the plans and send them to the EFSO. There is a backlog of 16 hours for these activities. The two-minute call from the DOW to the EFSO to schedule the bid is considered as a transportation time.

Block 3. PR will send a copy of the charge letter to the project's administrating agency in this case, a suburb. The administrative agency is responsible for organizing the bid to select the contractor, but the bid itself is administered through DOW. PR distributes hard copies of the project to the bidders, and a contractor is selected.

The time required to select the contractor is about 80 working hours, and is considered value-added time. At present there is a backlog of 560 hours within the legal department of the DOW. The winning contractor's takes 2-minute call to schedule the first preconstruction meeting is treated as transport time.

Block 4. The first preconstruction meeting will occur at DOW's downtown office. The meeting is attended by the contractor and personnel from DOW's utilities department. It is intended to plan for the re-routing of other utility services and traffic during construction. When the first preconstruction meeting is completed, PR sends a Letter to Proceed to the EFSO.

The first preconstruction meeting lasts for about one hour. After that, writing the Letter to Proceed takes about 15 minutes. This meeting

typically occurs two days after being scheduled, and this delay is considered NVA time. After this meeting, it is the contractor's responsibility to call the EFSO inspector to schedule the second preconstruction meeting. This takes 2 minutes, and is a transport time.

Block 5. The EFSO receives the Letter to Proceed from PR through internal DOW mail. The contractor calls the inspector, a DOW employee, to schedule the second preconstruction meeting at the construction site. There is sufficient time between the two preconstruction meetings so that the contractor can gather construction materials on-site. During the second preconstruction meeting the inspector verifies that the correct materials are on-hand.

The supplier will need two weeks to gather the materials. This is considered NVA time. The second preconstruction meeting will take about 15 minutes. After this meeting, the contractor calls the Permit and Sales (P&S) department located in downtown Cleveland to arrange for paying the fee. The 5-minute call is considered as transportation time.

Block 6. The contractor contacts the P&S department, to arrange payment of fees specified in the Charge Letter. These fees can be paid by the contractor in person at the P&S office, or by check through U.S. mail. After receiving the fee from the contractor, P&S releases the work orders for the project. P&S needs 2 hours to generate work orders. The work order authorizes the inspector to call the contractor to verify the start date of the construction.

Block 7. The contractor begins the construction work after the work orders have been released. The contractor will develop the as-builts as the work progresses. As-builts are drawings depicting all the modifications to the construction. They show how the construction was actually built, as opposed to how it was designed. In this phase, as-builts consist of hand written notes and drawings added to the project hard copies. In addition, the inspector inspects the progress of the work every day. The construction, is 150 days and of value-added time. The post-construction, call to schedule the chlorination test and is 2 minutes of travel time.

Block 8. A chlorination test is done to check for bacteria and to determine whether or not the water is potable. It takes about 5 to 7 working days. After this, the contractor performs a pressure test to check for leaks in the main. This takes about one day. There is a backlog of 20 hours before a chlorination test can begin. After the tests have been completed, the inspector calls the DOW and schedules the water main reconnection. This call takes 2 minutes and considered as transport time.

Block 9. The Tap crew department will connect the new construction to existing taps and mains. While doing the reconnection work, the Tap crew will also develop their own as-builts. The inspector will continue his daily inspections through this phase of the work. Reconnection takes about 100 working hours (value added time). After reconnection, the inspector contacts the contractor and instructs him to clean up the as-builts. The call takes about 3 minutes, and is transport time.

Block 10. The contractor updates the original drawings in AutoCAD to include the information included in the as-builts. He then submits the new hard copy to the inspector by hand. The contractor takes 2 days to clean the as-builts in AutoCAD. There is a backlog of about 3 days for this work. After completing the as-builts, the contractor will deliver the revised hard copies to the inspector. This takes about 30 minutes of travel time, depending on where the contractor's office is located.

Block 11. After receiving the clean as-builts from the contractor, the inspector goes to the site and compares them to the actual construction to verify that the information in the as-builts is accurate. The inspector will then submit the as-builts to the draftsman at the ESFO. The draftsman verifies the as-builts are drawn to DOW standards. When he judges that everything is acceptable, the draftsman sends the as-built hard copies to the mapping unit by DOW mail.

The inspector's review takes 20 minutes and the draftsman's review takes 15 minutes. Both these operation are value added times. There is backlog of about 23.8 hours with the inspector and draftsman estimated by multiplying the time per review by the number of reviews pending for the both employees. Sending the as-builts to the Mapping unit by DOW mail takes one day.

Block 12. The mapping unit scans the as-builts and sends the scans to the GIS department electronically in a .TIF format. The hard copies are kept for the mapping unit's records. The mapping unit takes about 1 hour to

scan drawings, and 15 minutes to send them. The scan time is considered as value-added, while the send time is considered as travel time. In addition, there is a backlog of 2 hours at the mapping unit.

Block 13. The GIS department updates the information in the GIS database, referring to the scanned files. This takes about 3 hours.

III.3 Proposal-to-Construction Time

As mentioned before, it takes 19 weeks from the time a project is proposed to the DOW to the time construction is allowed to begin. The process blocks that are involved in this are 2 through 6 in the current state map. By compiling the value-added times, non-value-added times, and transport times, a timeline for the proposal-to-construction segment of the VSM may be developed (Fig 3). The timeline shows that there is a total of 23 weeks (91 working hours) of value-added time, 16.8 weeks of non-value-added time, and a mere 0.2 hours of transport time between proposal and construction. The bulk of this 19-week period is the 70-day delay during the bidding process.

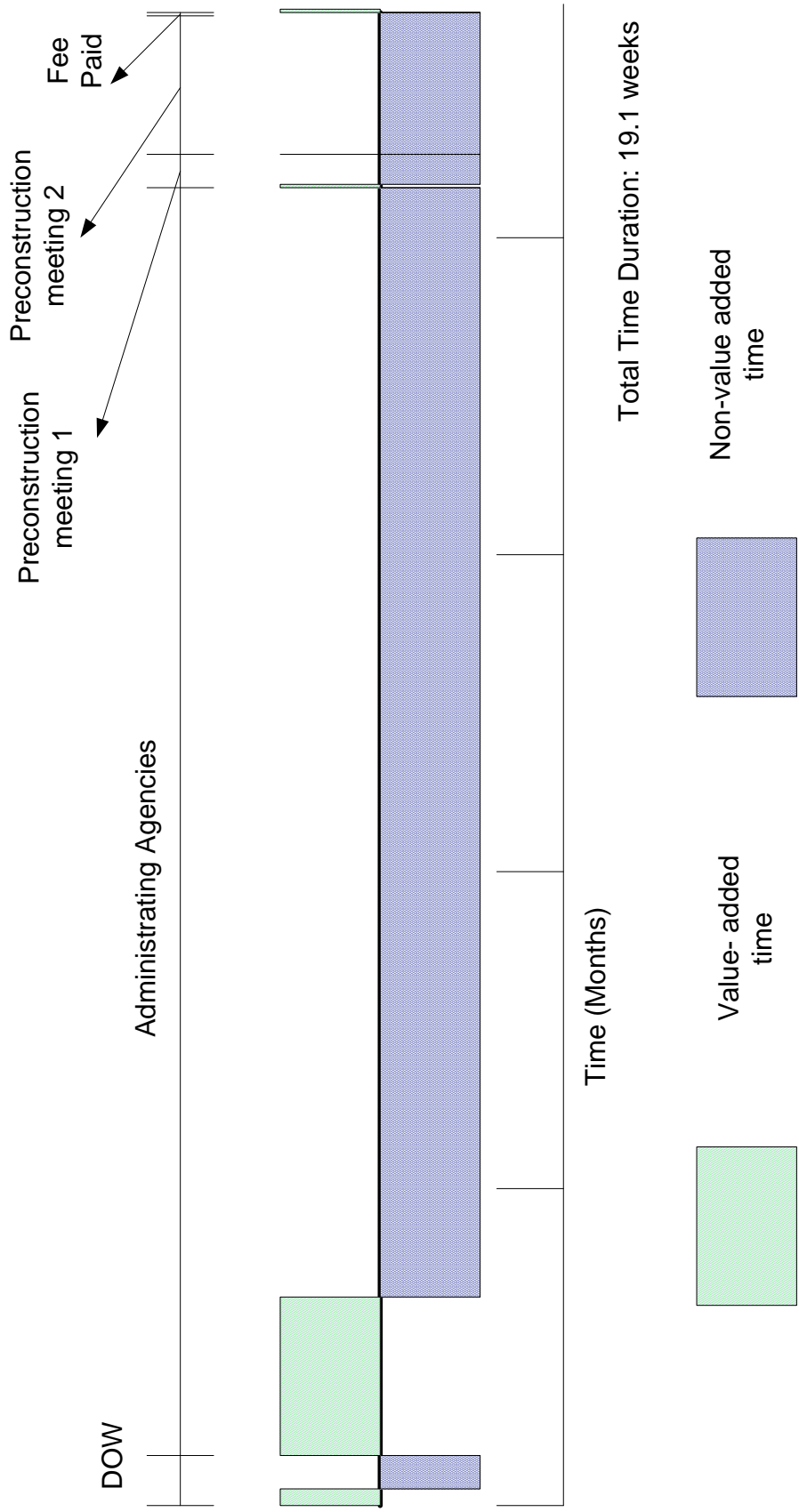


Fig 3: Water Main Replacement Project, Proposal-to-Construction, Current State, Timeline

III.4 As-builts from contractor to GIS database

As done in section III.4, the value-added times, non-value-added times, and transport times in blocks 8 through 13 are summed to develop the timeline for capturing data from the as-builts (Fig. 4). The total value-added time is 4.1 weeks; non-value-added time is 1.9 weeks, and transport is 0.2 week. Unlike the proposal-to-construction timeline, the as-built timeline does not show a single significant source for NVA time.

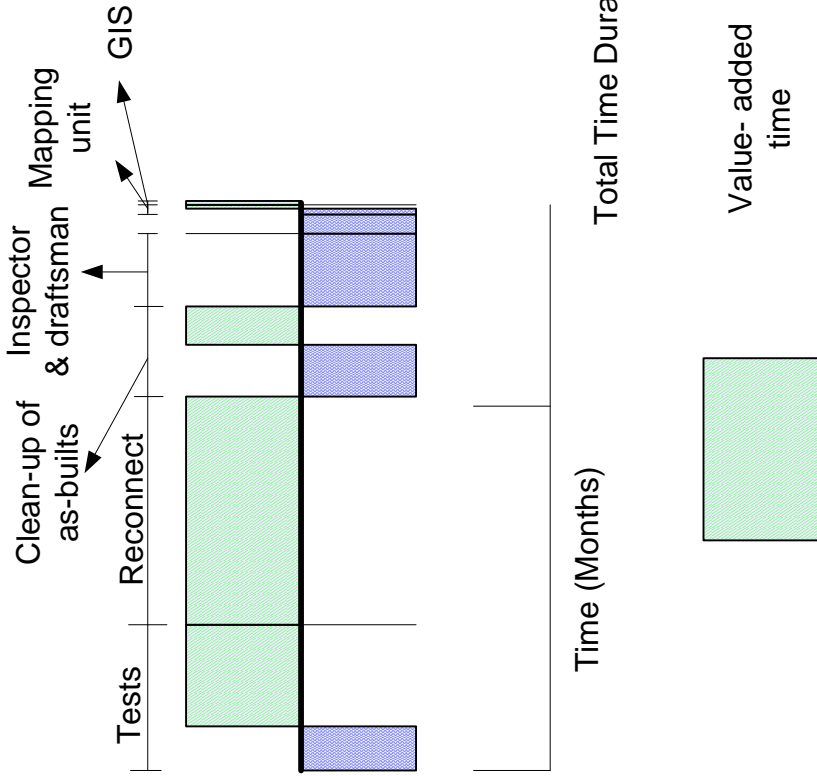


Fig 4: Water Main Replacement Project, As-Builts to GIS, Current State, Timeline

CHAPTER IV

FUTURE STATE MAP

Chapter III detailed the process steps for handling information on DOW projects. Table II summarizes the non-value-added times found in each process step. The block number refers to the process block in the current state map (Fig.2).

Process Step	Non-value added & Travel times
Block 1	10 days of non value added with engineering firm because of other projects. 1 day for transportation of plans by U.S mail to PR
Block 2	2 day Backlog in PR
Block 3	70 day backlog in the DOW legal department
Block 4	2 day delay with the contractor due to multiple, simultaneous projects
Block 5	10 day wait to gather material at the jobsite
Block 6	N/A
Block 7	N/A
Block 8	20 hour backlog between the tests due to poor scheduling
Block 9	N/A
Block 10	3 day backlog with the contractor due to multiple, simultaneous projects
Block 11	3.9 day backlog with the inspector and draftsman. 1 day for transportation of plans by DOW mail to PR
Block 12	2 hour backlog in the mapping unit
Block 13	N/A

Table II: Details of Non-Value Added Times in the Current State, Water Main Replacement Project

Having identified the NVA activities such as delays and bottlenecks present in the current state, it is now possible to discuss a one-year implementation plan to improve projects. These recommendations address the major source of delay in the proposal-to-construction time, and in the timely submission of as-builts.

IV.1 Proposal-to-Construction Recommendations

A water main replacement project, going from proposal to construction, passes through blocks 2 through 6 in the current state map (Fig. 2). Looking at Table II, there is a 70-day (14-week) backlog in block 3, which covers the bidding process for selecting a contractor. This is the most significant delay, comprising 74% of the total time between a project's proposal and the time its construction begins. It is obvious, then, that this backlog should be addressed.

In addition to meeting national engineering codes and standards, contractors submitting bids to the DOW must meet certain legal requirements. A recent Request for Proposal from the City of Cleveland, for example, requested that the contractor "use good faith efforts to hire residents of the City of Cleveland and... meet the City's minority representation goals" [25]. The legal guidelines a bidding contractor must follow are not clear, can be confusing, and are difficult for the contractor to follow. The DOW does not provide contractors with a comprehensive checklist for meeting legal requirements on submission. As a result, every bid must be reviewed by the DOW legal staff, and contractors contacted for clarification or correction of legal and policy forms found in the bid. The amending of bids is an example of rework in an office process, which contributes greatly to the 70-day delay in processing bids.

It is recommended that the legal and procedural guidelines for proposal submission be consolidated and simplified to make it easier for both the contractor to complete the necessary forms, as well as the DOW legal department to review and approve the same. A one-stop service, analogous to Cleveland State University's "Campus 411" program, could help contractors navigate through the regulations of bidding on a DOW project. Based on other Lean implementations, it is feasible that the 70-day backlog can be reduced by 50% within a one-year span. Doing this will reduce the proposal-to-construction time from 19.1 weeks to 12.1 weeks. Figure 5 shows the future-state timeline with this change implemented.

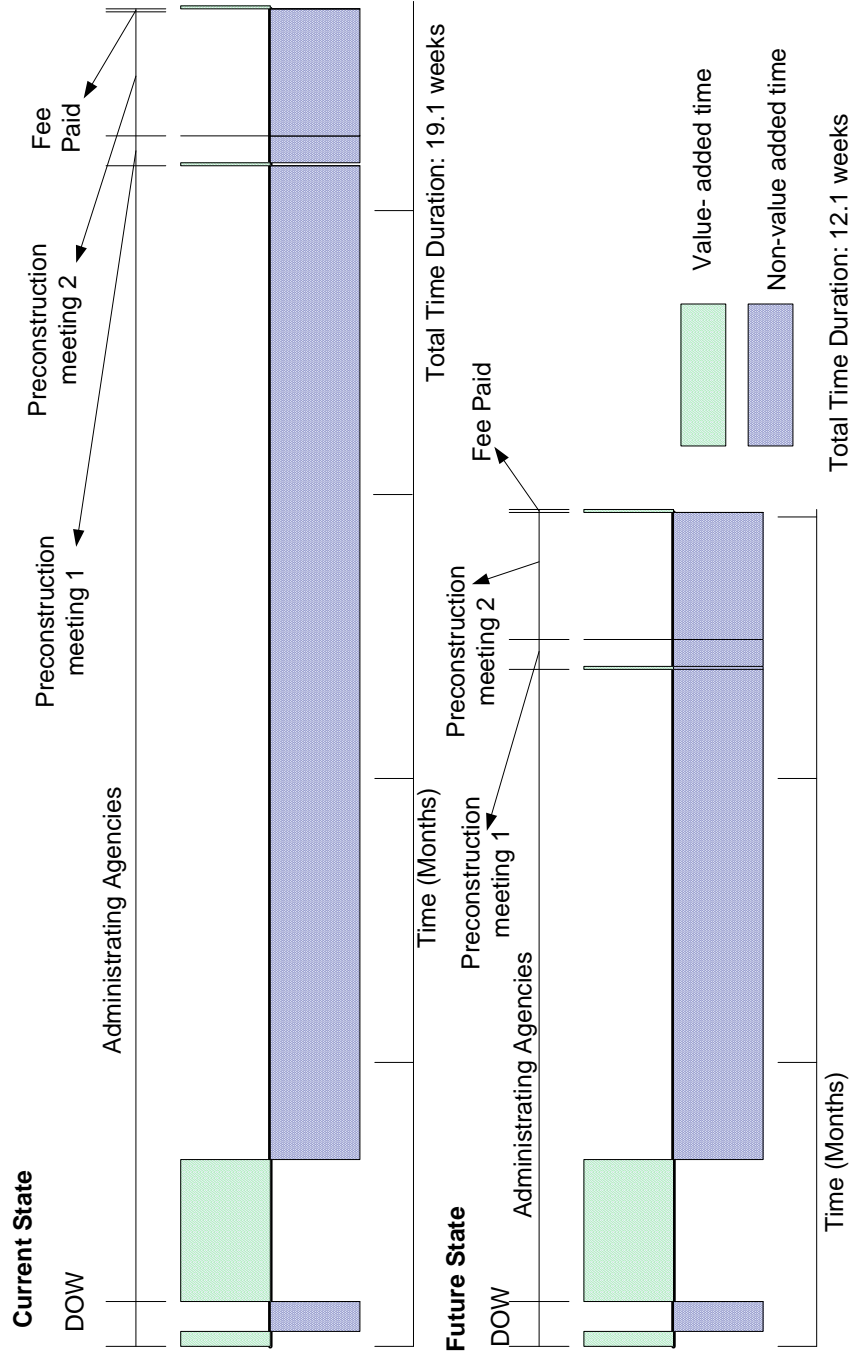


Fig 5: Water Main Replacement Project, Proposal-to-Construction, Future State, Timeline

IV.2 As-Built-to-GIS Recommendations

Unlike the proposal-to-construction phase, there is no single large source for the backlog in getting the as-built information into the GIS database. Much of the time in the timeline of Fig. 2 is value-added, but the value stream map and the timeline can still be used to find opportunities for improving this process.

It is noted that there is a 3.9-day delay in block 11, representing the time projects wait for review by the inspector and the draftsman. It is noted that the draftsman's review of the hard copies duplicates much of the work performed by the inspector, and that the additional value added by the draftsman is negligible. It is recommended, therefore, that the draftsman be removed from the process and assigned other duties within the DOW. Doing this will remove 3.5 days of backlog from the EFSO.

It is further recommended that as-built drawings be submitted to the inspector electronically, in the native AutoCAD format. Once the inspector has reviewed the work, he can send the approved files electronically to both the mapping unit and the GIS unit at the same time. This has a number of advantages. Electronic communication is faster than mail delivery of hard drawings, saving one day of transport time. The mapping unit does not add any value to the as-built drawings; it only translates the hard copies to an electronic format for the GIS unit. Further, the GIS unit may be able to directly import relevant data from an AutoCAD format ("cut-and-paste"), while the .TIF format requires a GIS technician to enter all the information manually into the database. There is a time saving of at least one day in this recommendation. Figure 6 shows the as-built-to-GIS timeline being reduced from 6.2 to 5.2 weeks. More importantly, these recommendations free personnel to perform other duties for the DOW.

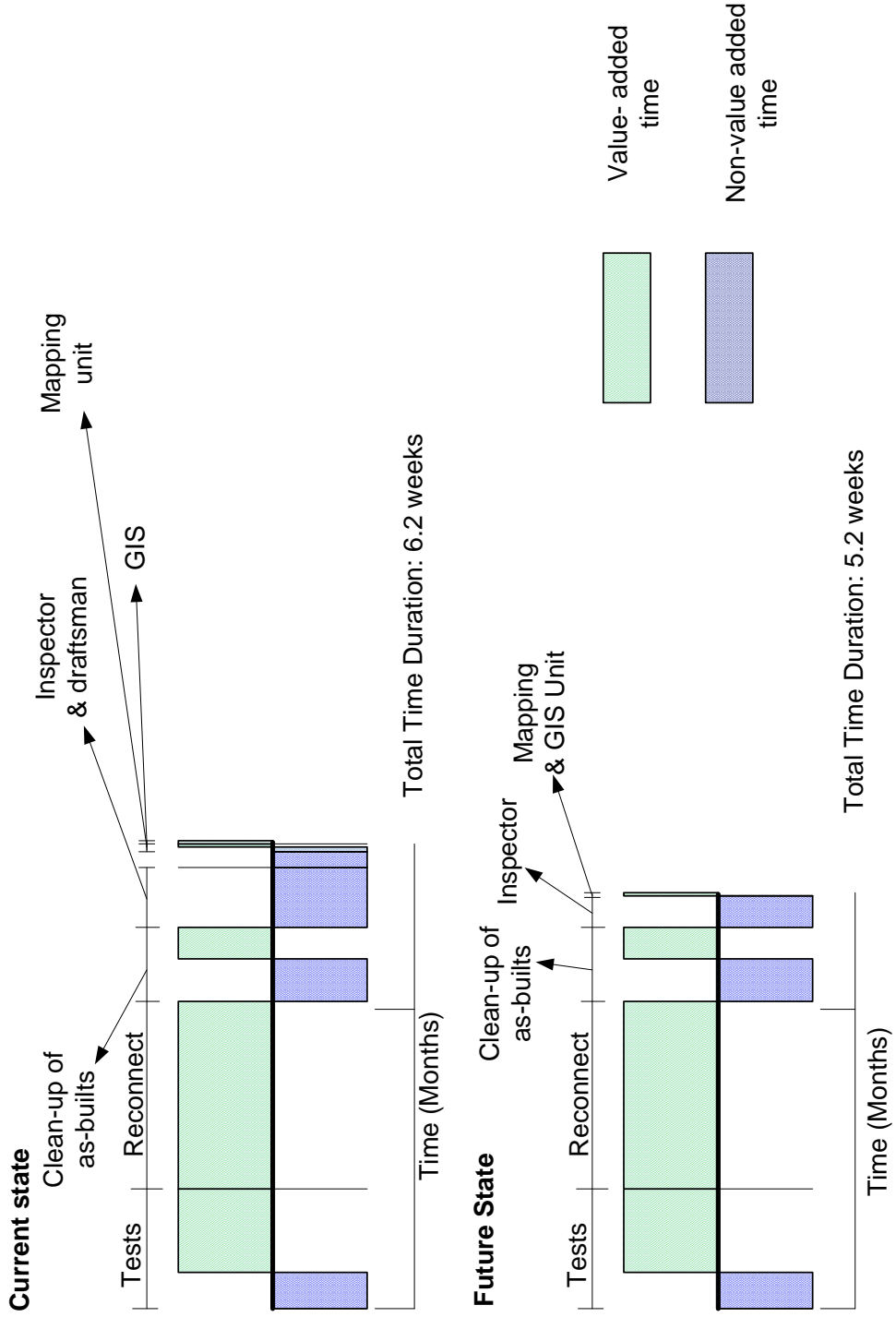


Fig 6: Water Main Replacement Project, As-Builts to GIS, Future State, Timeline

IV.3 Future state map

By implementing the recommendations for a water main replacement project listed in sections IV.1 and IV.2, a future state map can be drawn. Figure 7 shows the map. That the overall project time, excluding construction, has dropped from 39.5 weeks to 21.3 weeks. The recommendations are possible for the DOW to implement within a time span of one year.

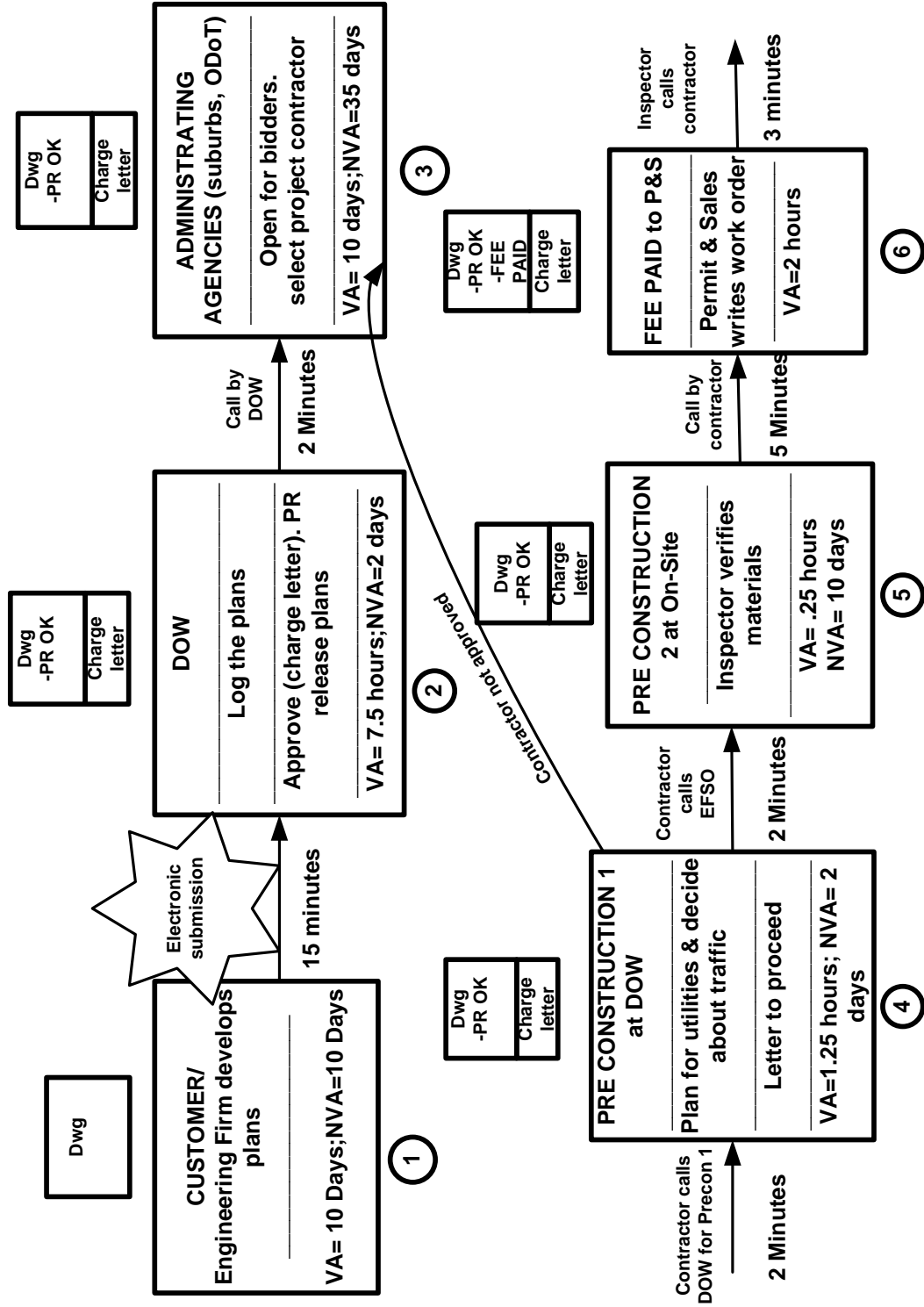
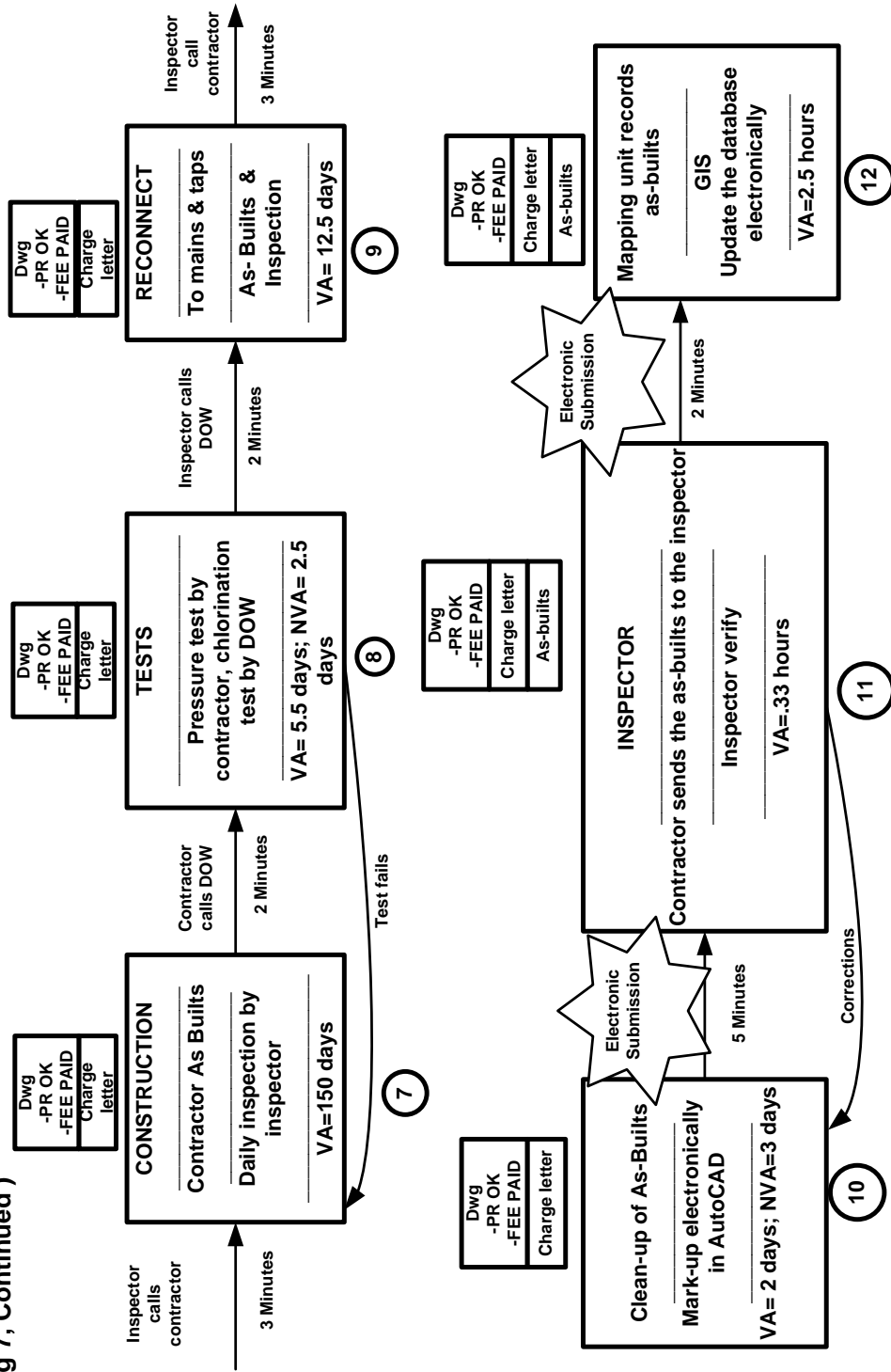


Fig 7: Water Main Replacement Project, Future State

(Fig 7, Continued)



IV.4 Other Project Classifications

The current state map of the figure 2 and future state map of figure 7 represent a typical water main replacement project. The DOW projects may fall under five additional project classifications. Table III presents the key differences between the other DOW projects and a water main replacement project. These differences are found in both the present and future state maps. Table IV presents the total value-added, non-value-added, and transport times for the six DOW project classifications.

Project Type	Key Differences
Sewer	Block 2-One extra hour of VA time, to check for conflict between the proposed sewer work and existing water lines.
Road widening & road reconstruction	Block 2-One extra hour of VA time, to check for any requirement of water work.
Freeway, bridge and other utility	Block 2-One extra hour of VA time, to check for a requirement for water work. Block 8-One additional day of VA time to install meters. Block 13-One extra hour (or whatever is needed) of VA time for GIS to update the initial meter.
Distribution main new installations and water main extension	Block 8-One additional day of VA time to install meters. While backlog is more by 2.5 days. Block 13-One extra hour (or whatever is needed) of VA time for GIS to update the initial meter.
Cleaning and lining	Block 8-4 fewer hours of VA time, and 4 fewer hours of backlog. A pressure test is not required due to this project being performed on existing construction.

Table III: Key Differences between Water Main Replacement and Other DOW Projects

Project Type	Proposal-to-Construction Time	As-Built to GIS Time
Water main replacement, relocation & lowering	Current State VA: 91 hrs NVA: 672 hrs Travel: .2 hrs Total: 19.1 hrs	Current State VA: 164.33 hrs NVA: 77.2 hrs Travel: 8.38 hrs Total: 6.2 hrs
	Future State VA: 91 hrs NVA: 392 hrs Travel: .2 hrs Total: 12.1 hrs	Future State VA: 162.83 hrs NVA: 44 hrs Travel: .2 hrs Total: 5.2hrs
Sewer	Current State VA: 91 hrs NVA: 672 hrs Travel: .2 hrs Total: 19.1 hrs	Current State VA: 164.33 hrs NVA: 77.2 hrs Travel: 8.38 hrs Total: 6.2 hrs
	Future State VA: 91 hrs NVA: 392 hrs Travel: .2 hrs Total: 12.1 hrs	Future State VA: 162.83 hrs NVA: 44 hrs Travel: .2 hrs Total: 5.2 hrs
Road widening & road reconstruction	Current State VA: 92 hrs NVA: 672 hrs Travel: .2 hrs Total: 19.1hrs	Current State VA: 164.33 hrs NVA: 77.2 hrs Travel: 8.38 hrs Total: 6.2 hrs
	Future State VA: 92 hrs NVA: 392 hrs Travel: .2 hrs Total: 12.1 hrs	Future State VA: 162.83 hrs NVA: 44 hrs Travel: .2 hrs Total: 5.2 hrs

Table IV: Times for Different Project Classifications

<p style="text-align: center;">Distribution main new installations & water main extensions</p>	<p>Current State VA: 91 hrs NVA: 672 hrs Travel: .2 hrs Total: 19.1 hrs</p> <p>Future State VA: 91 hrs NVA: 392 hrs Travel: .2 hrs Total: 12.1 hrs</p>	<p>Current State VA: 172.83 hrs NVA: 93.2 hrs Travel: 8.38 hrs Total: 6.9 hrs</p> <p>Future State VA: 171.33 hrs NVA: 60 hrs Travel: .2 hrs Total: 5.8 hrs</p>
<p style="text-align: center;">Cleaning & lining</p>	<p>Current State VA: 91 hrs NVA: 672 hrs Travel: .2 hrs Total: 19.1 hrs</p> <p>Future State VA: 91 hrs NVA: 392 hrs Travel: .2 hrs Total: 12.1hrs</p>	<p>Current State VA: 160.33 hrs NVA: 73.2 hrs Travel: 8.38 hrs Total: 6.0 hrs</p> <p>Future State VA: 158.83 hrs NVA: 40 hrs Travel: .2 hrs Total: 4.9 hrs</p>

Table IV (continued)

CHAPTER V

DISCUSSION AND CONCLUSIONS

Value Stream Mapping is a powerful tool to eliminate waste and make the supply chain of any organization Lean and responsive. VSM can be done in the same way for practically any business activity, and can be expanded upstream and downstream to encompass the entire supply chain. This powerful tool not only highlights process inefficiencies and transactional and communication mismatches, but also guides the organization in improving these areas.

Companies can apply the value stream mapping tool in the office the same way as on the shop floor. However, there are some distinct differences between the office and the shop floor. This thesis considers the flow of information, rather than physical goods. The goods on the shop floor are manufactured sequentially, where the information in the office is in multiple places at one time. Even many parties can modify it at the same time. Secondly the office processes are loosely structured. The information is generally transferred by paper or electronically. These processes often vary in scope. For example, a simple valve repair/replacement does not require much time for DOW review and

approval. At the other extreme, a large project such as the Euclid Corridor, which required the reconstruction of an eight-mile length of city street, required over two years of actual construction. Likewise, the office processes supporting DOW projects similarly vary in scope. The valve repair/replacement project is routine and may be completed quickly; the planning for a project on the scale of the Euclid Corridor can last over a year. This is different from shop processes in which the task times are usually standardized and predictable. Finally the office value streams are rarely contained in a single department. For example, customer service might be involved in quoting, order entry, invoicing, and telemarketing.

Companies often view administrative departments such as human resources, finance, engineering, and purchasing, as independent contributors to its success. They do not see the interaction and integration of the work activities involving multiple functions and departments. It is no wonder then, that companies have difficulty grasping the concepts of a new value stream design for the office. A company can overcome the inherent challenges of value stream management in the office by identifying and redesigning one or two value streams to begin with, then adding more as it continues its Lean transformation. When mapping the shop floor, a cross-functional team follows the path of a product and draws a visual representation of what they observe. For the office, it is typically a service, which may or may not result in a tangible product, that is the basis of the mapping observations.

The seven wastes described by Ohno are overproduction, inventory, waiting, extra processing, correction, excess motion, and transportation. Other authorities have added underutilized people as an eighth waste. These wastes are generally present in every

governmental organization. Most government agencies desire, on an organizational level, to deliver first-class service to their customers, yet this often does not happen. Once an agency uses VSM, then it can see the wastes in its processes. A future state map will guide the agency in collecting and eliminating the wastes. Governmental organizations that successfully implement Lean will deliver better customer service at a lower cost to the public.

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APPENDIX

SEWER PROJECTS

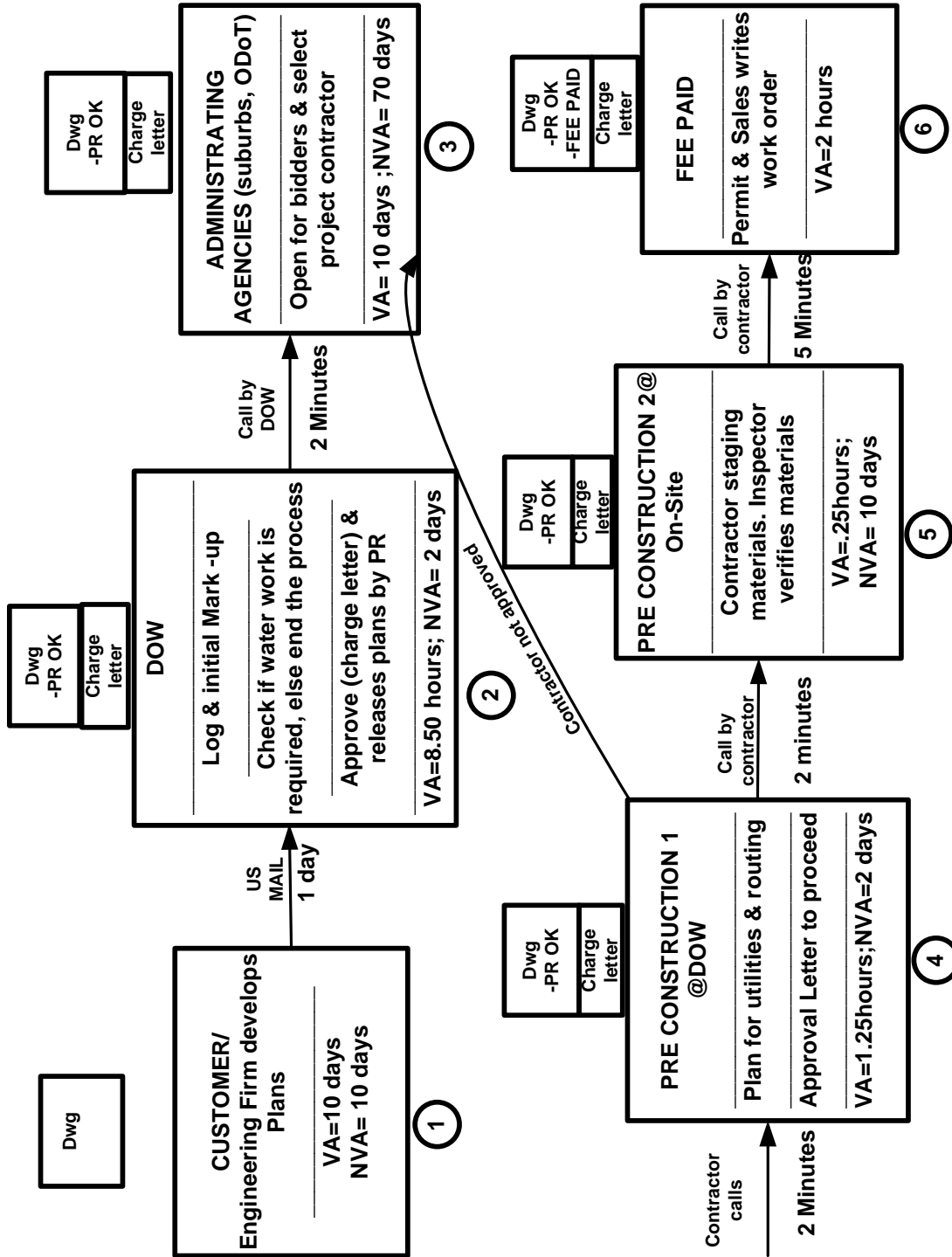
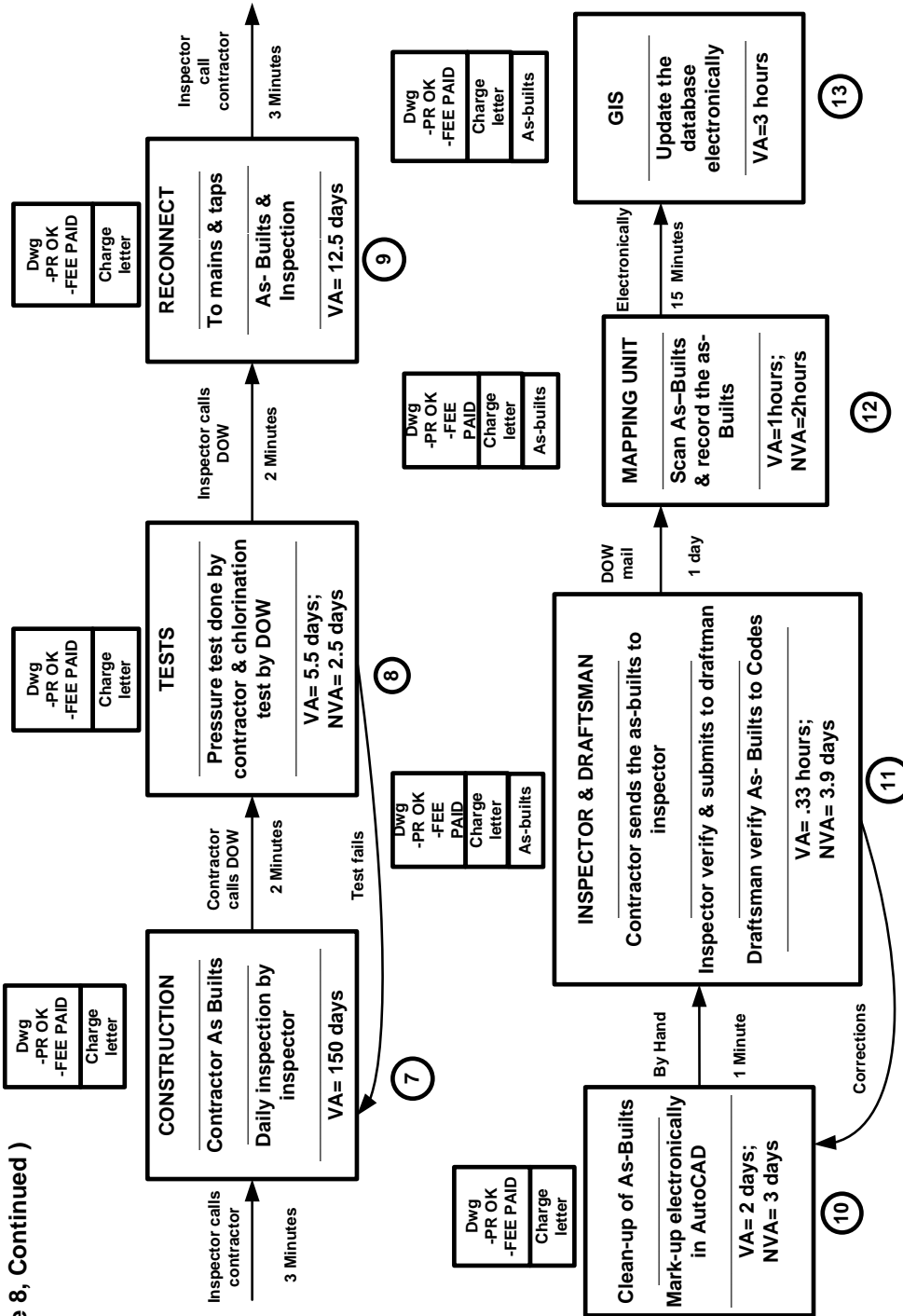


Fig 8: Sewer Project, Current State Map

(Figure 8, Continued)



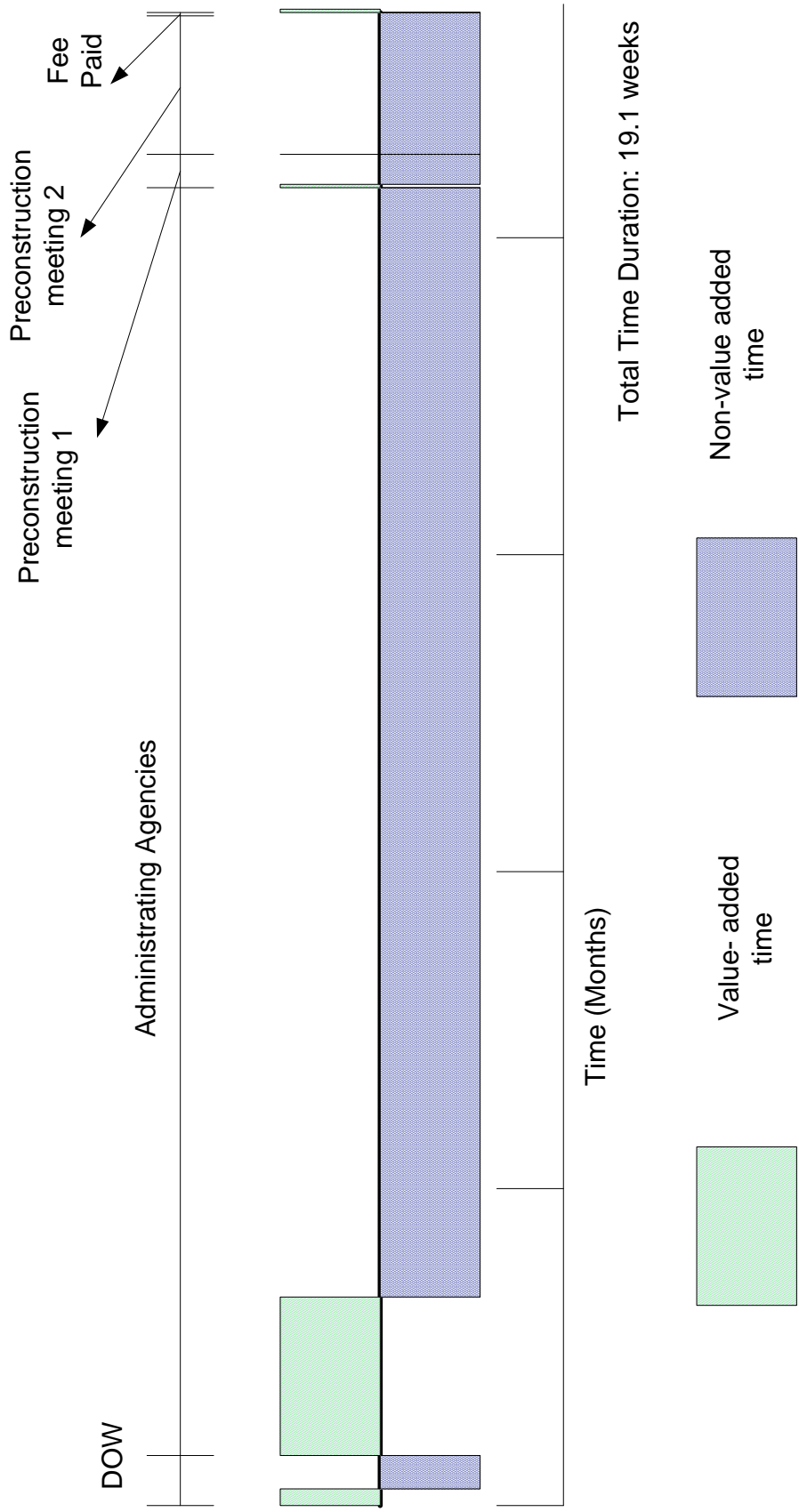


Fig 9: Sewer Project, Proposal-to-Construction, Current State, Timeline

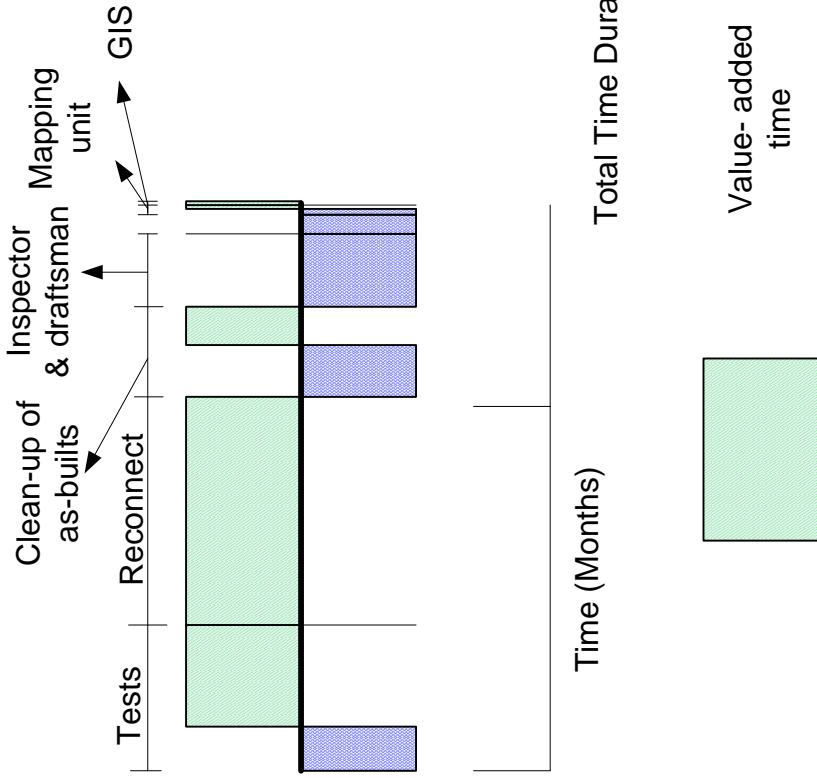


Fig 10: Sewer Project, As-Builts to GIS, Current State, Timeline

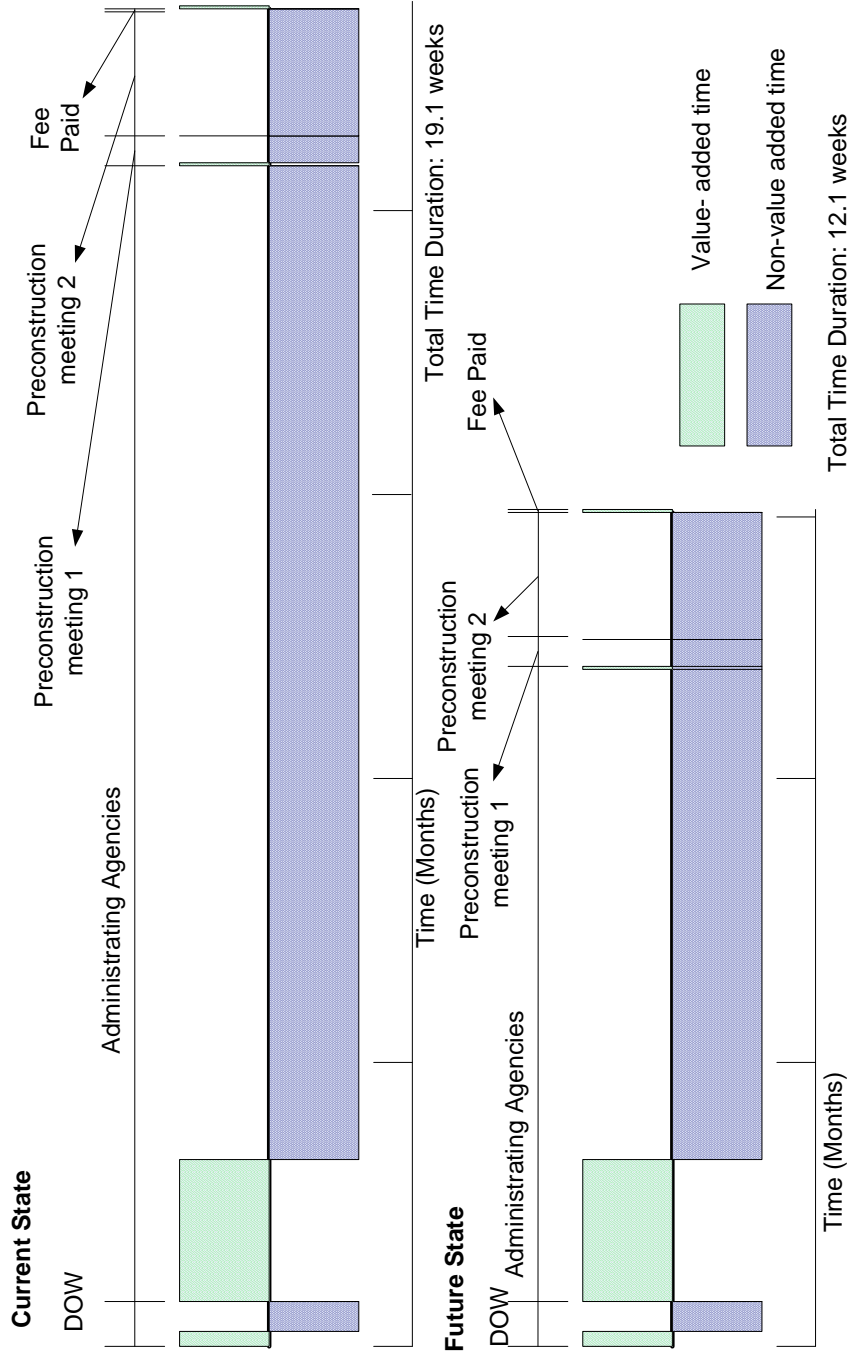


Fig 11: Sewer Project, Proposal-to-Construction, Future State, Timeline

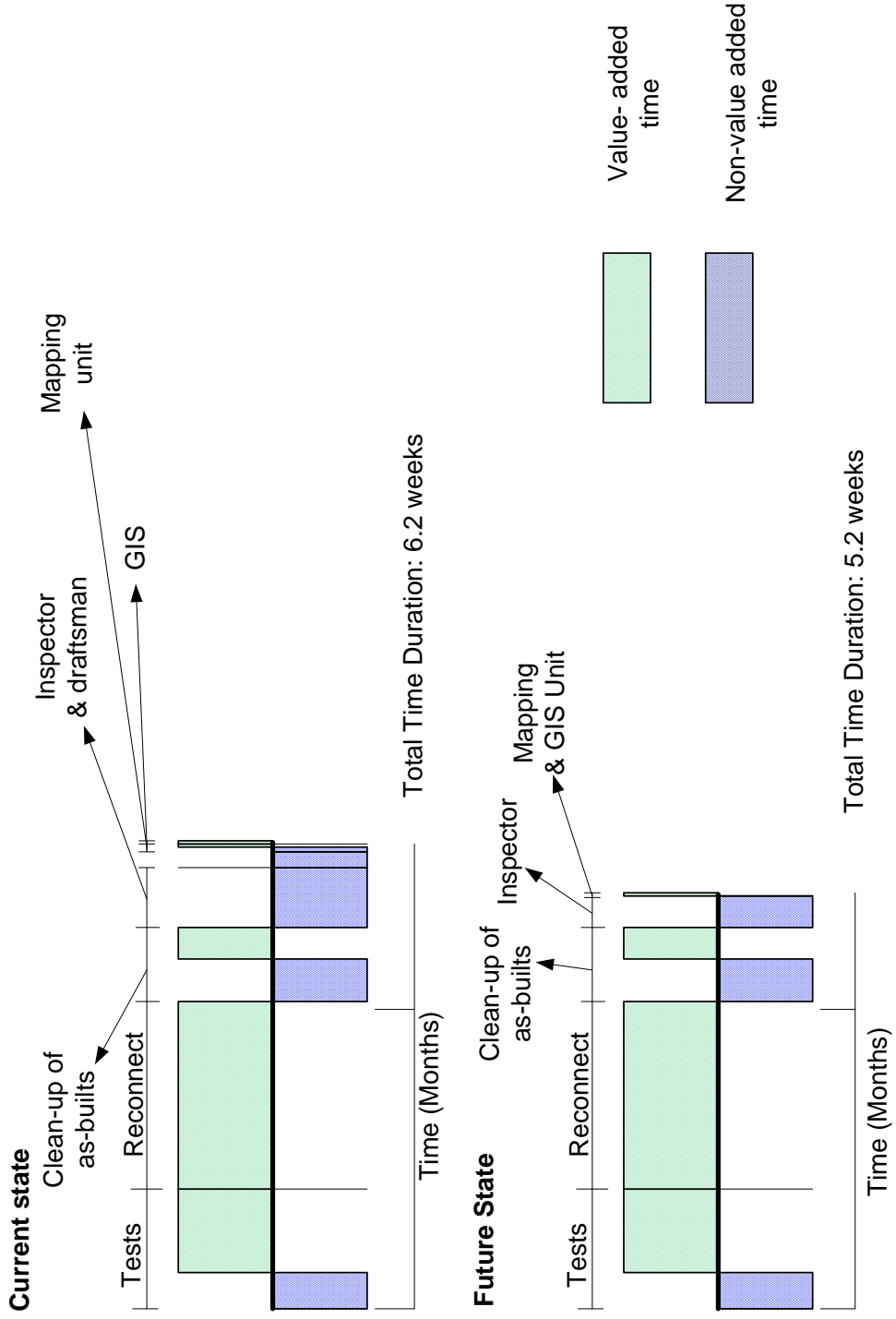


Fig 12: Sewer Project, As-Builts to GIS, Future State, Timeline

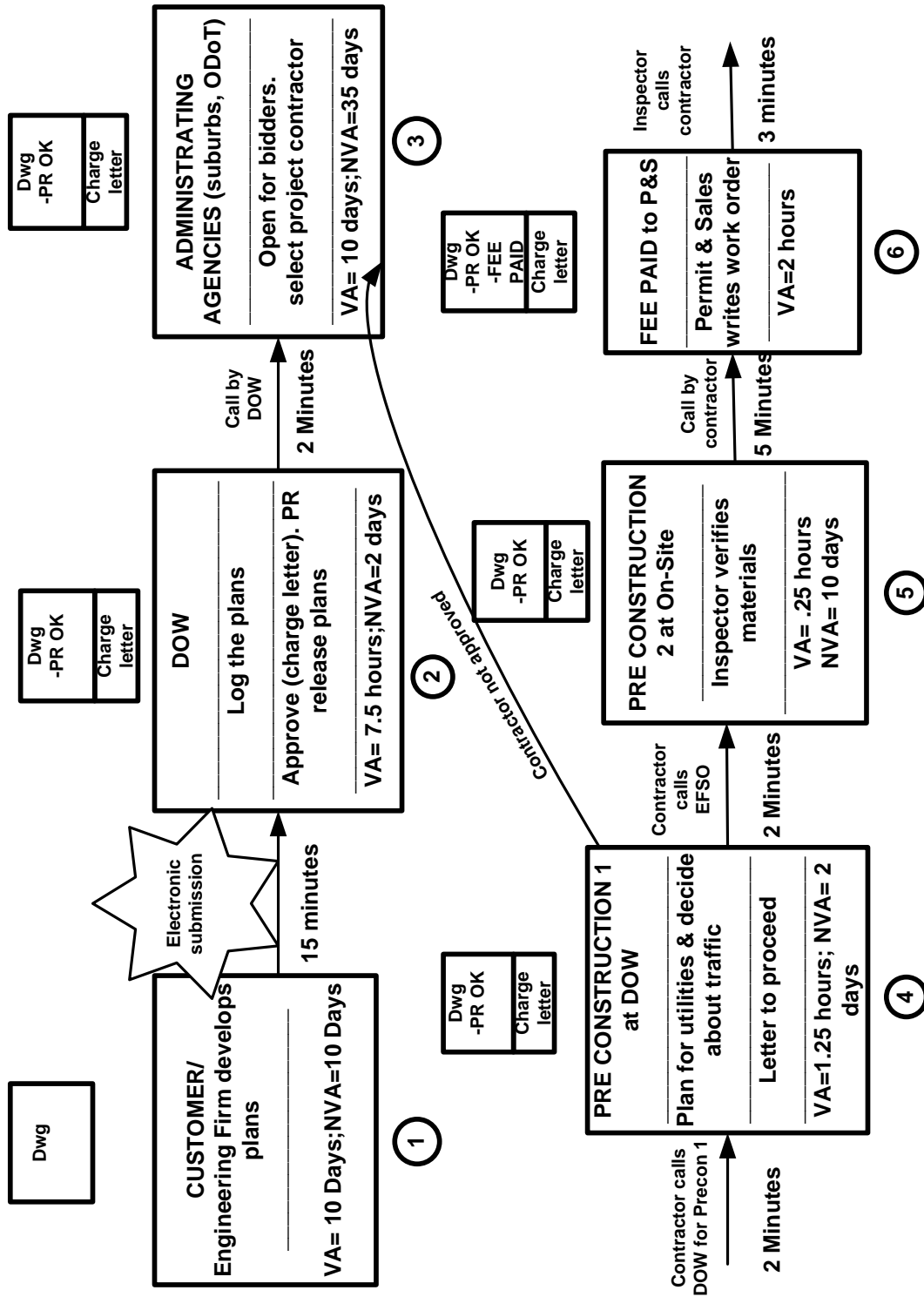
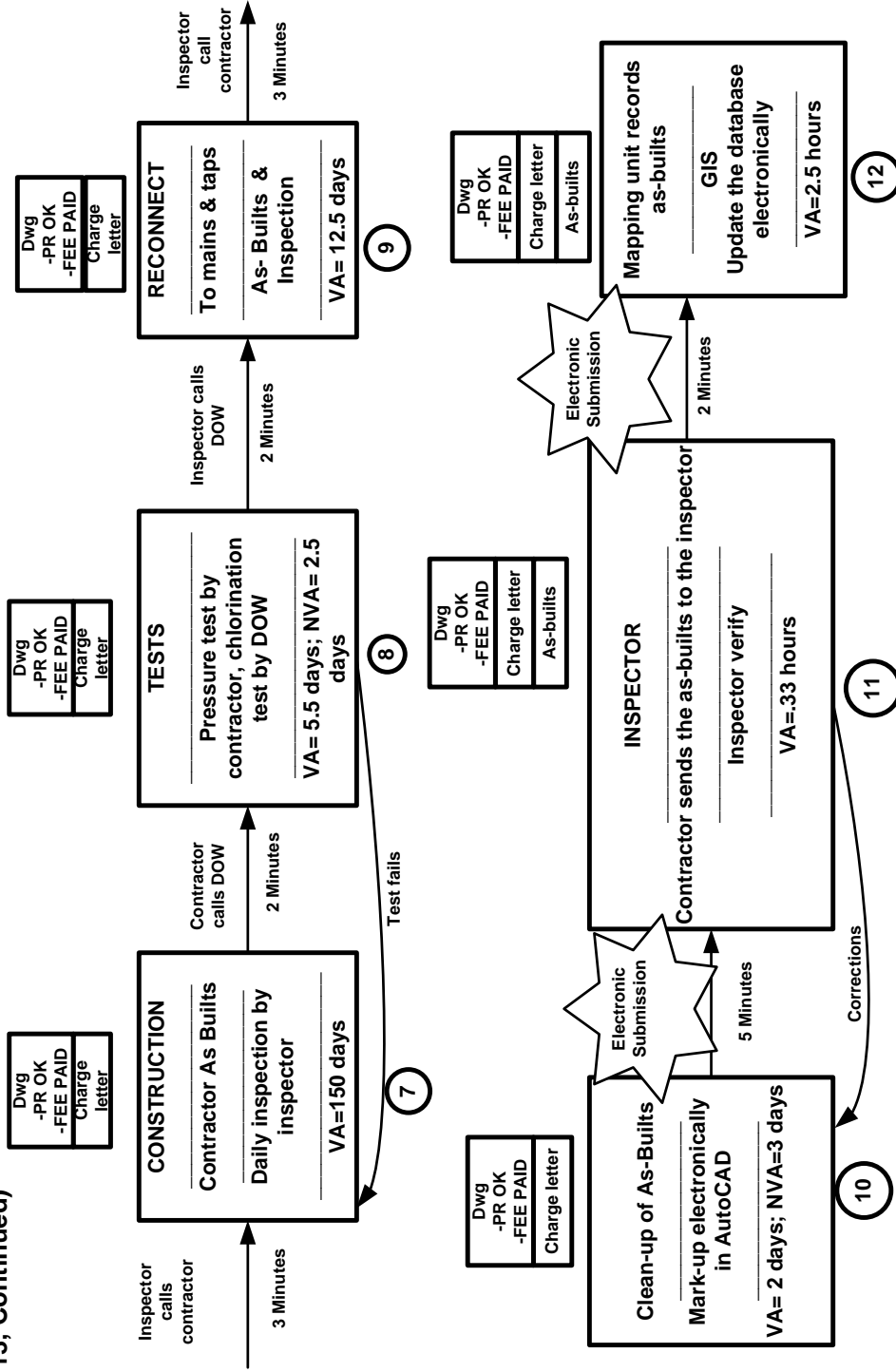


Figure 13: Sewer Project, Future State Map

(Figure 13, Continued)



ROAD WIDENING & ROAD RECONSTRUCTION PROJECTS

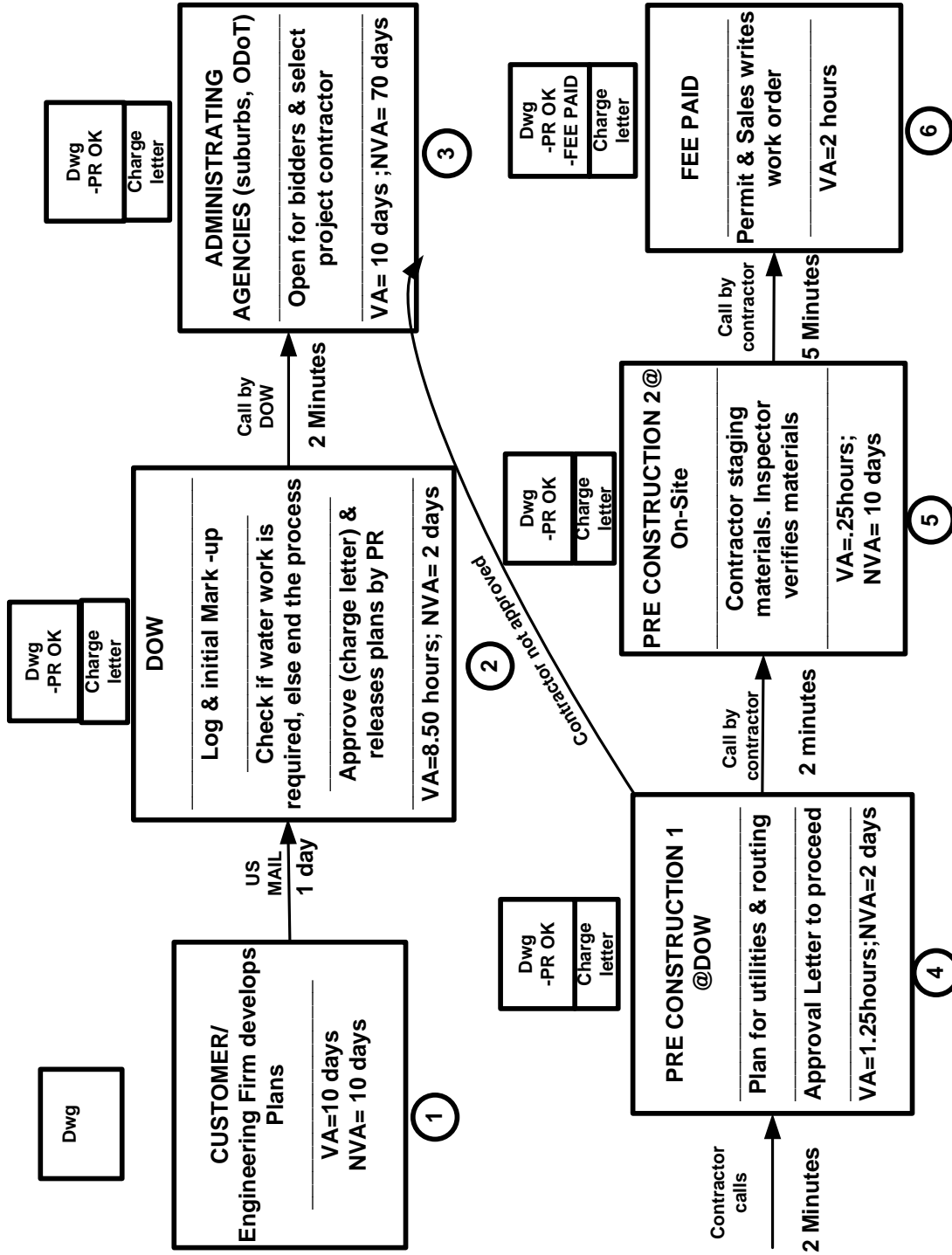
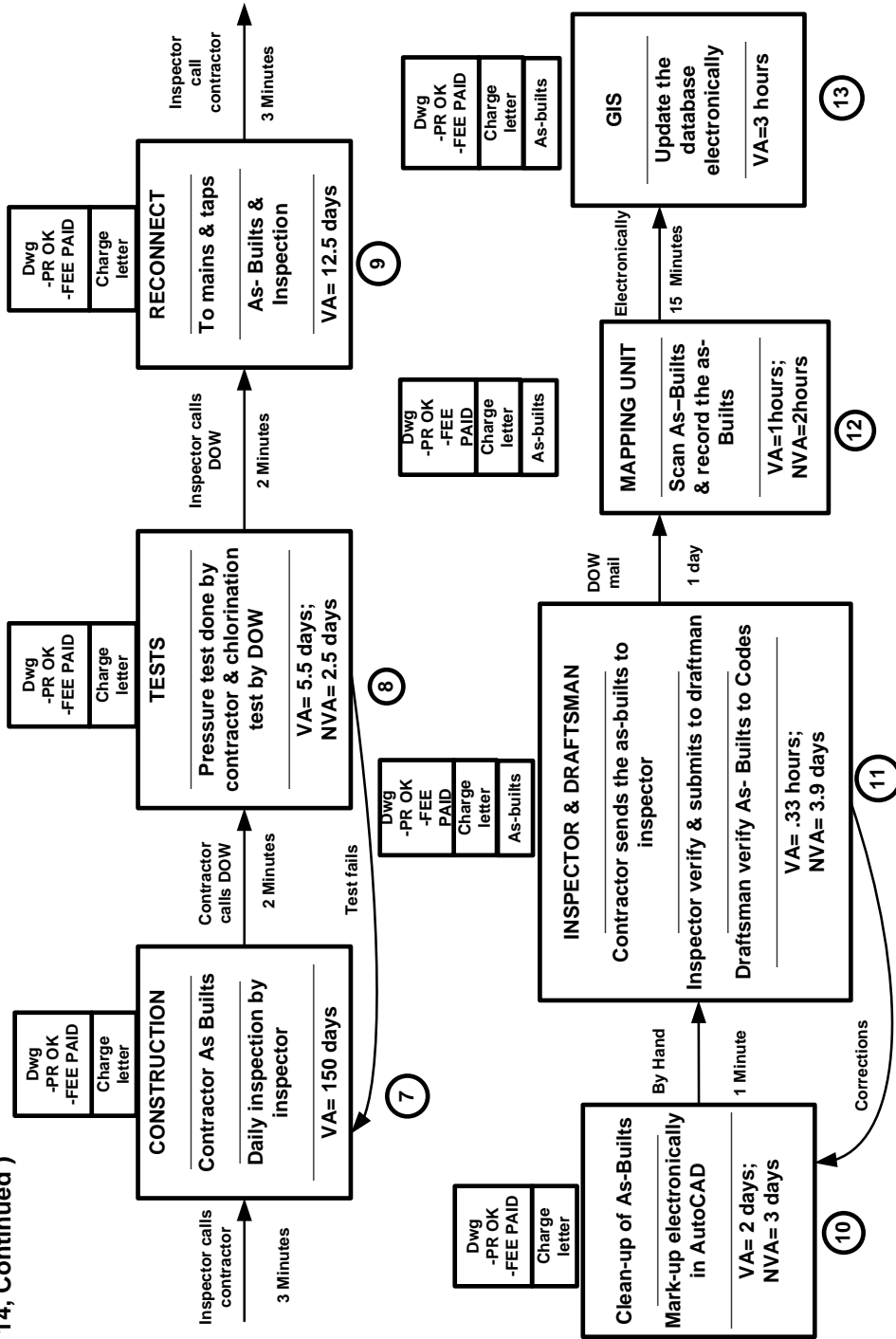


Fig 14: Road widening and road construction Project, Current State Map

(Figure 14, Continued)



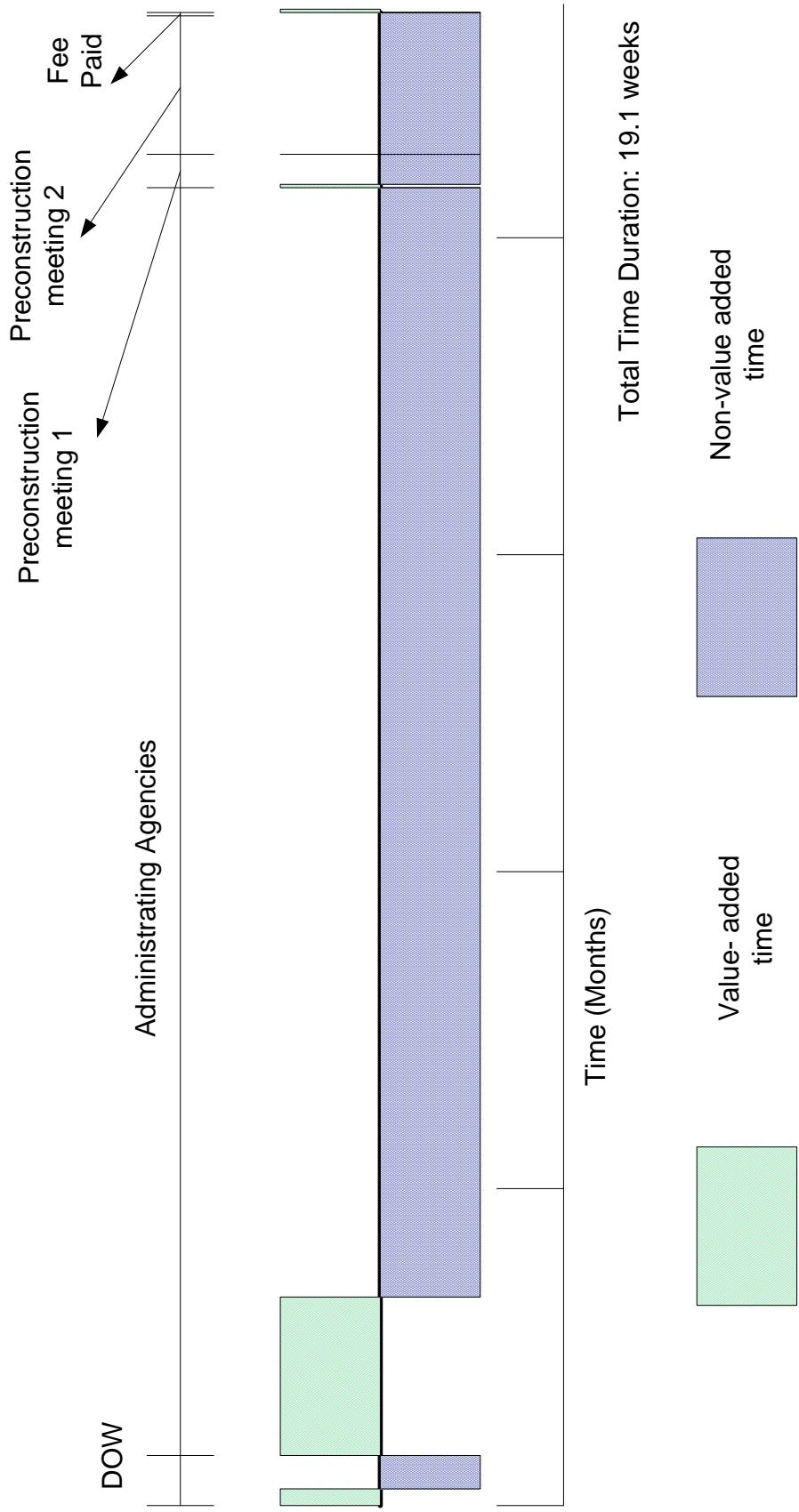


Fig 15: Road widening & road reconstruction Project, Proposal-to-Construction, Current State, Timeline

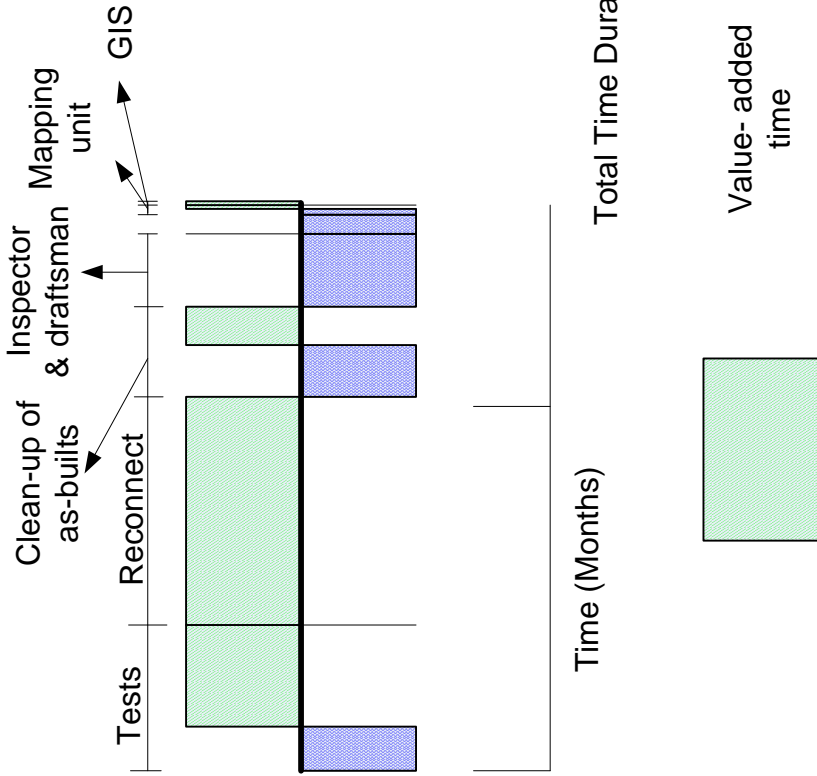


Fig 16: Road widening & road reconstruction Project, As-Builts to GIS, Current State, Timeline

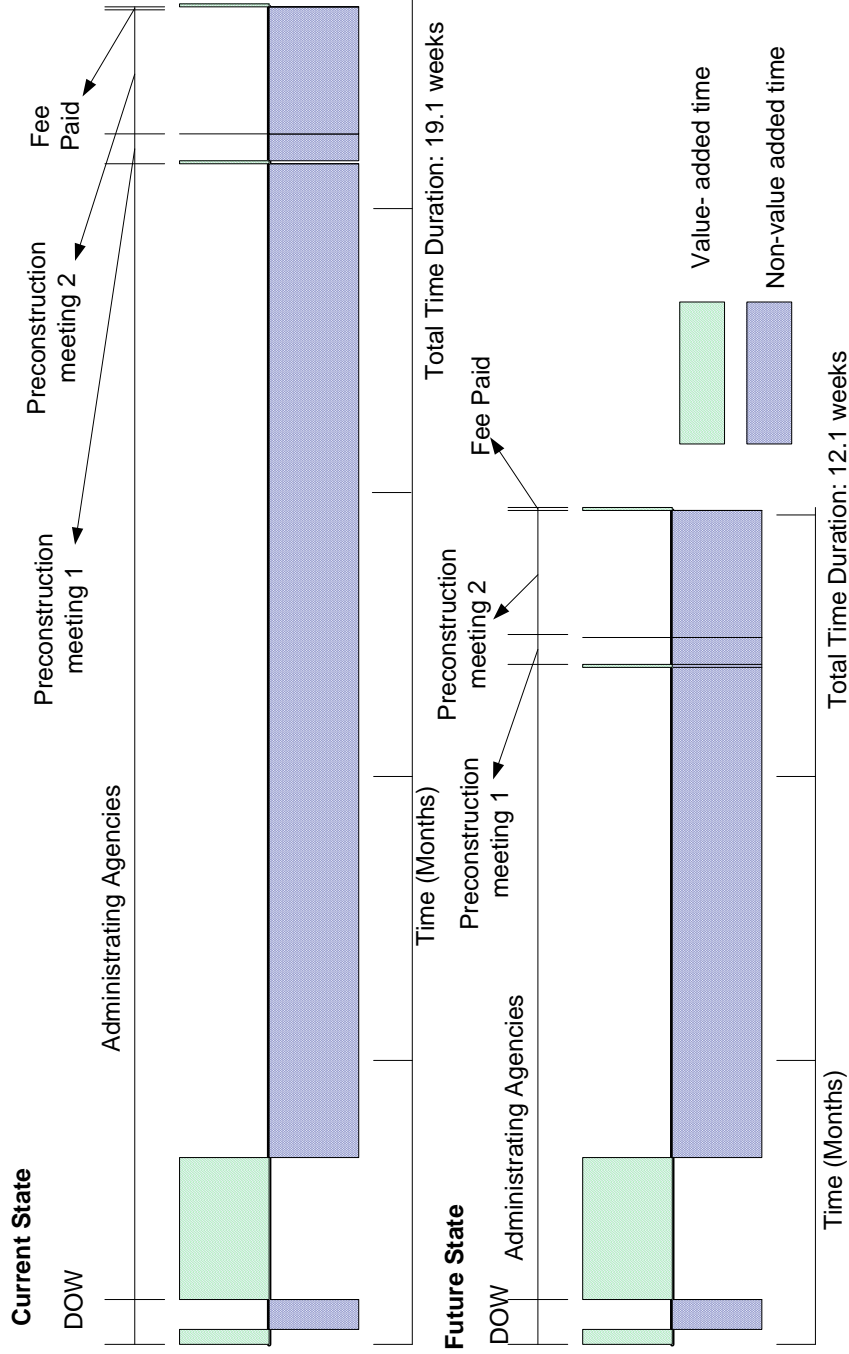


Fig 17: Road widening & road reconstruction Project, Proposal-to-Construction, Future State, Timeline

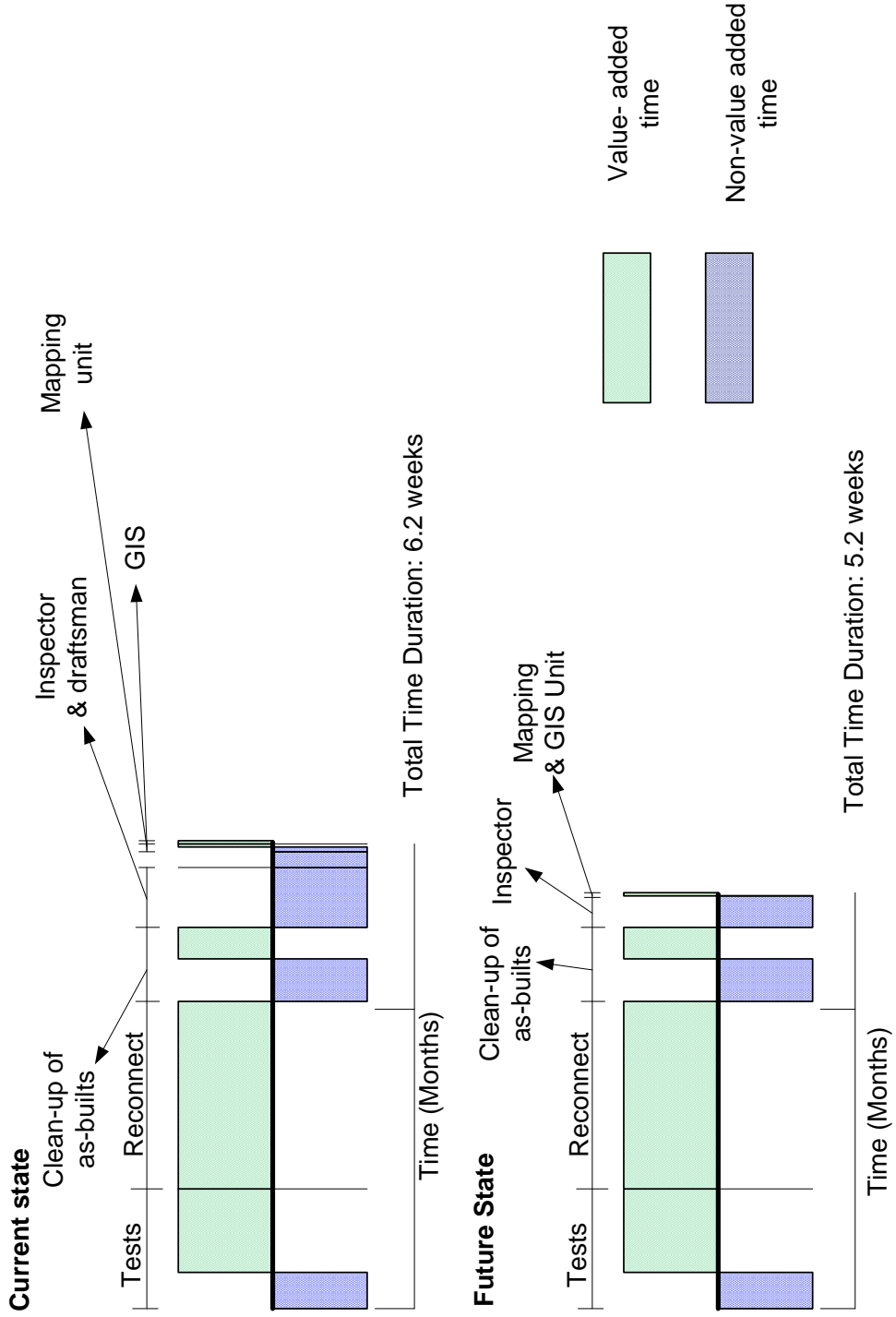


Fig 18: Road widening & road reconstruction Project, As-Builts to GIS, Future State, Timeline

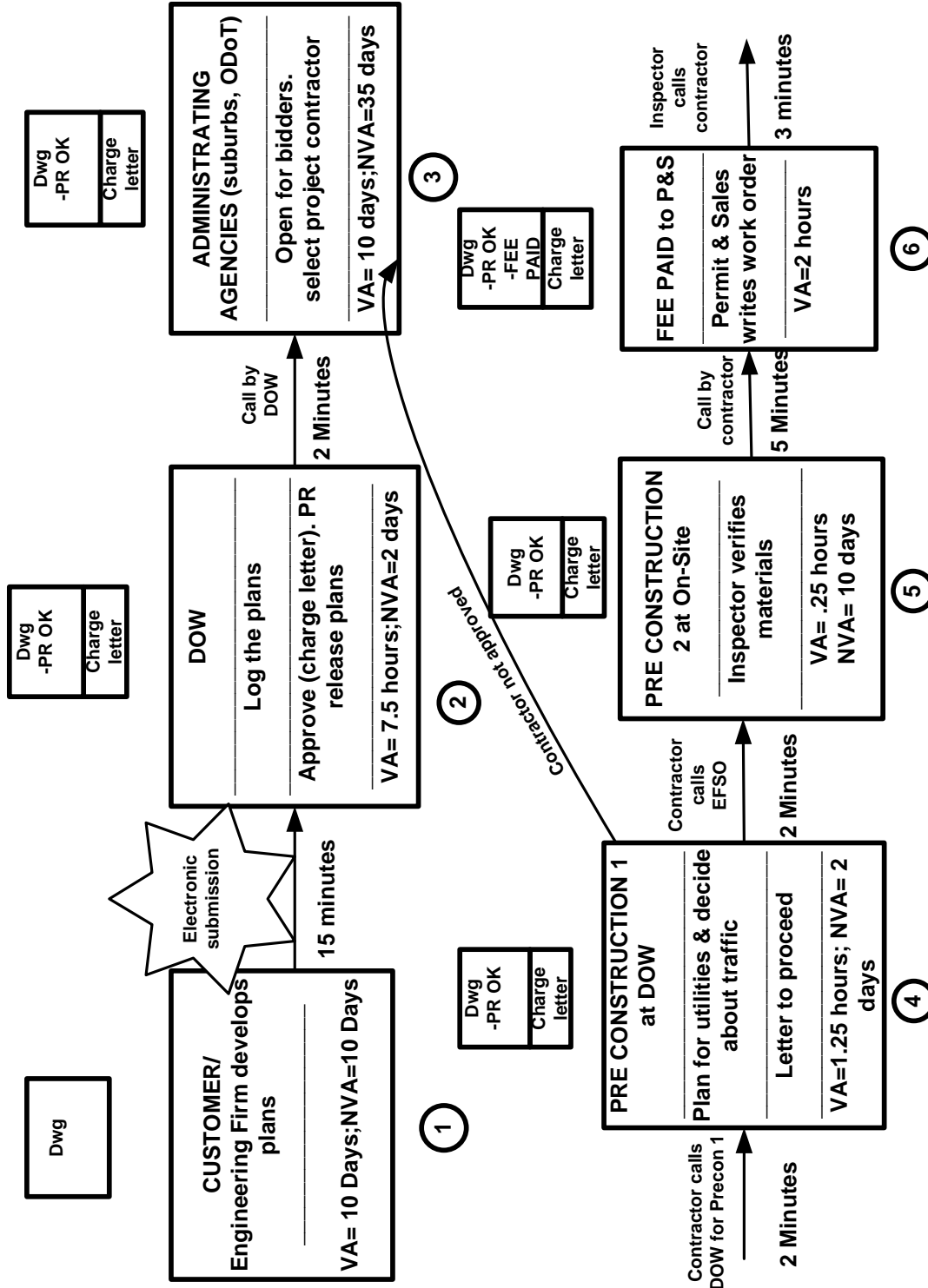
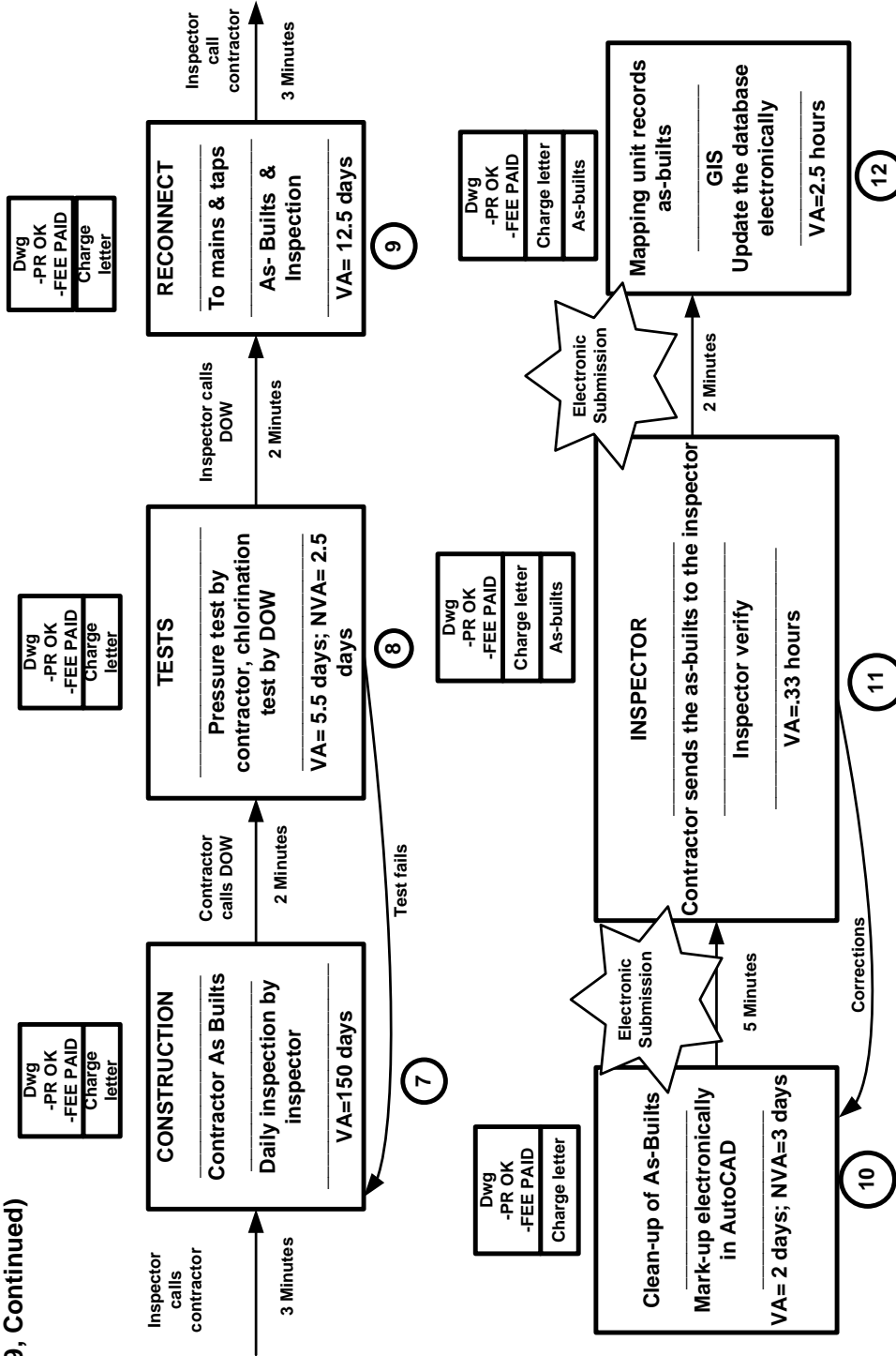


Fig 19: Road widening & road reconstruction Project, Future State

(Fig 19, Continued)



FREEWAY, BRIDGE & UTILITY PROJECTS

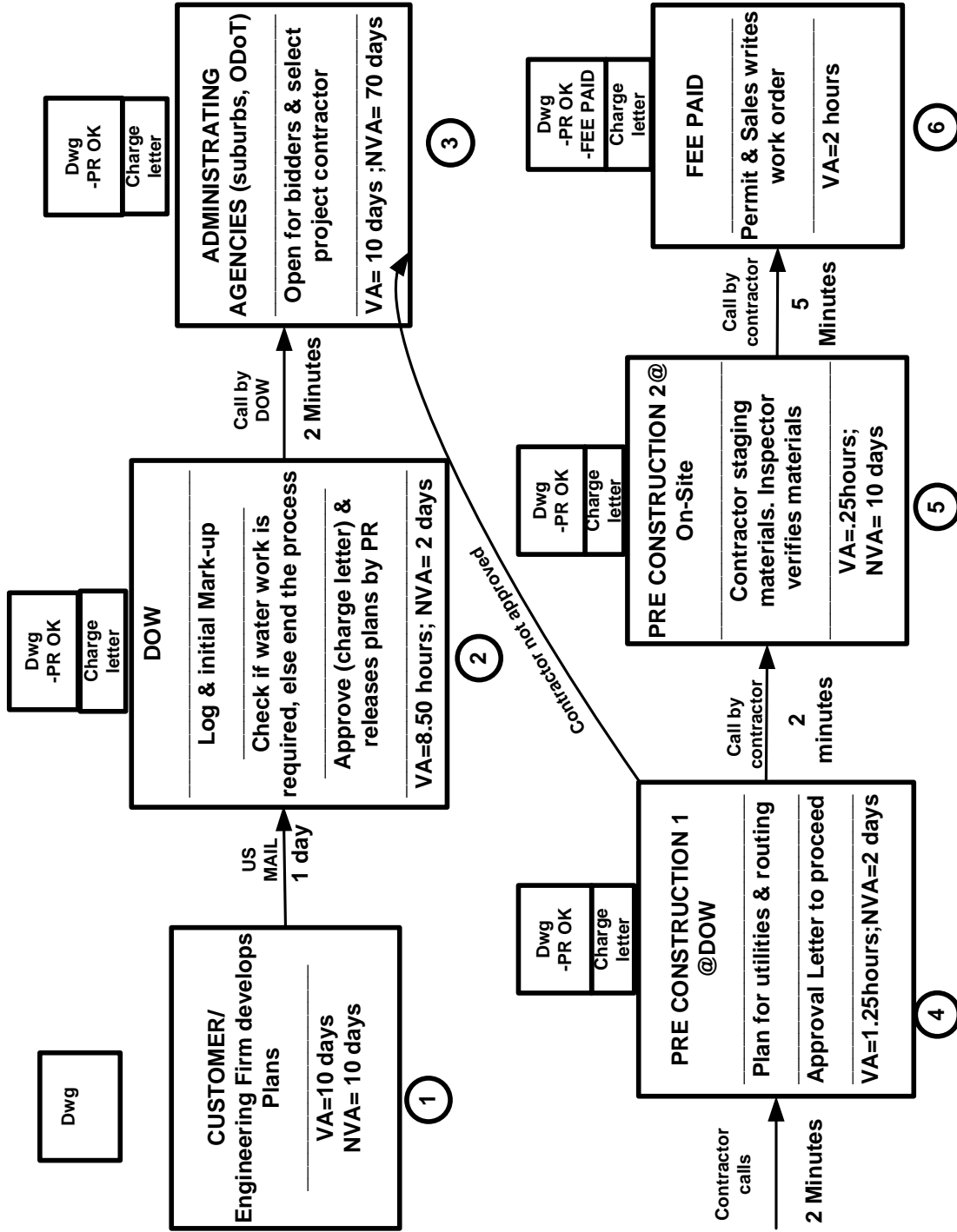
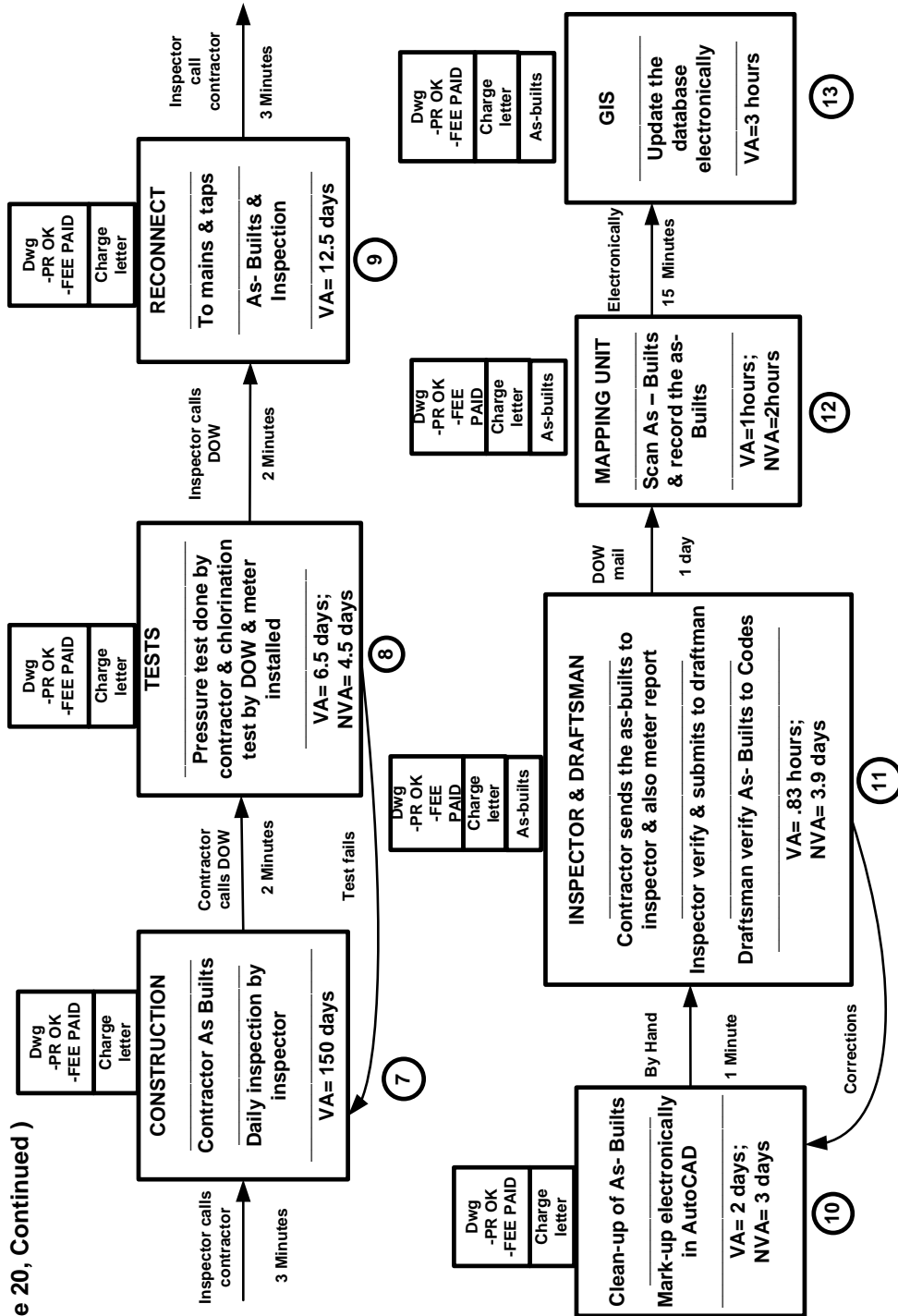


Fig 20: Freeway, Bridge & other utility Project, Current State Map

(Figure 20, Continued)



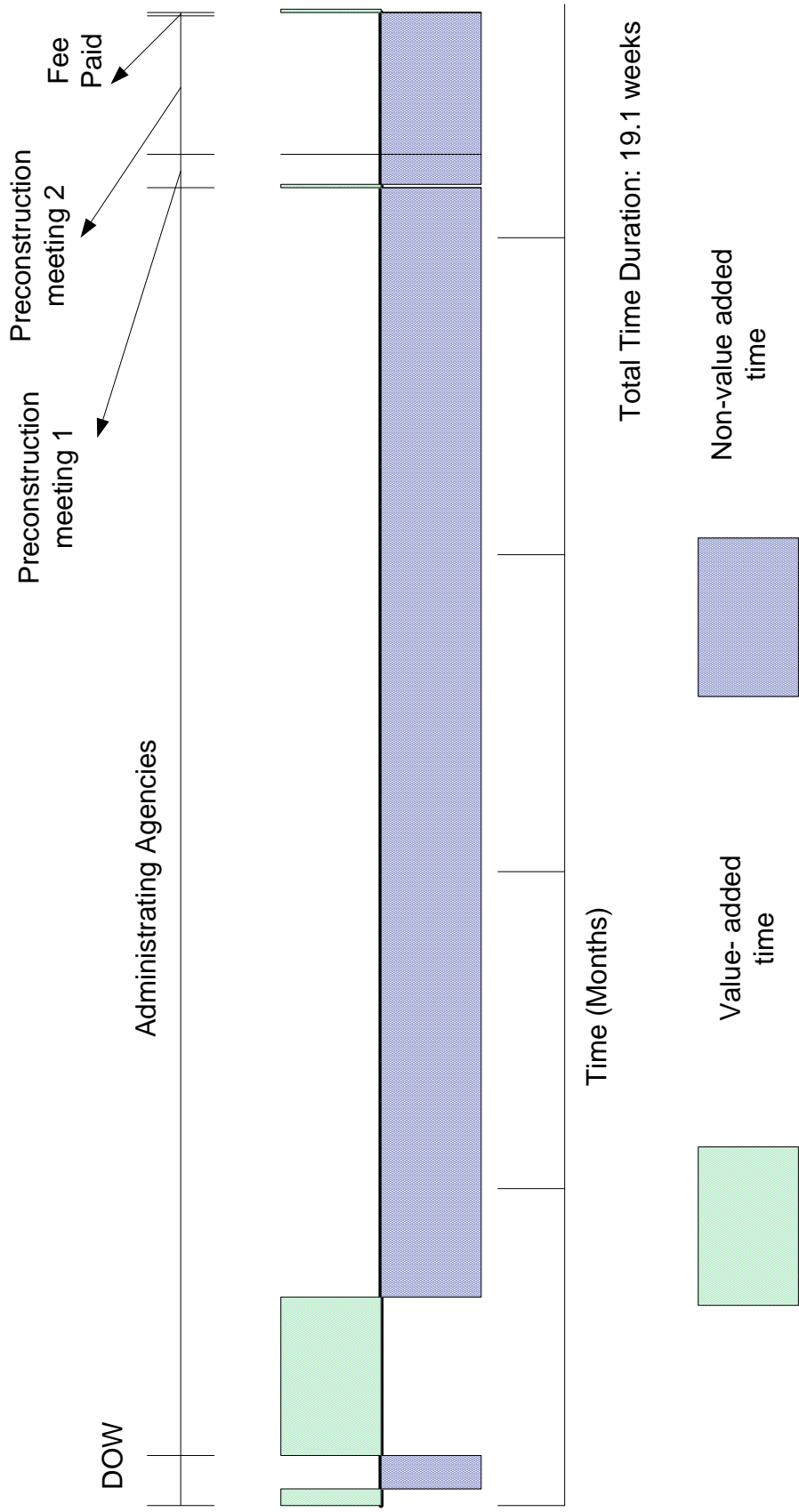


Fig 21: Freeway, bridge & other utility project, Proposal-to-Construction, Current State, Timeline

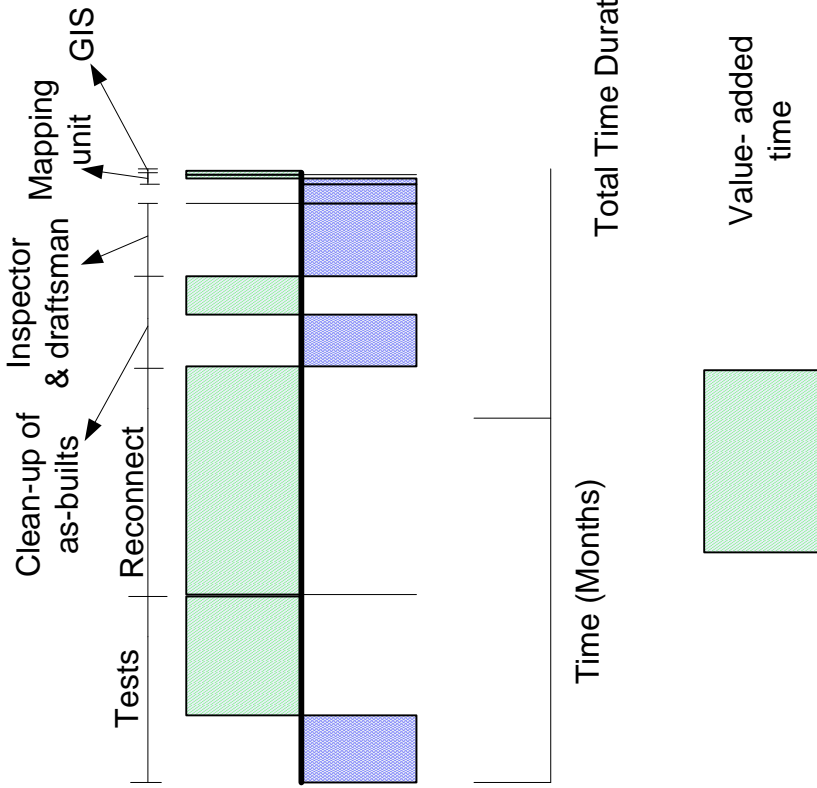


Fig 22: Freeway, Bridge & Other Utility Project, As-Builts to GIS, Current State, Timeline

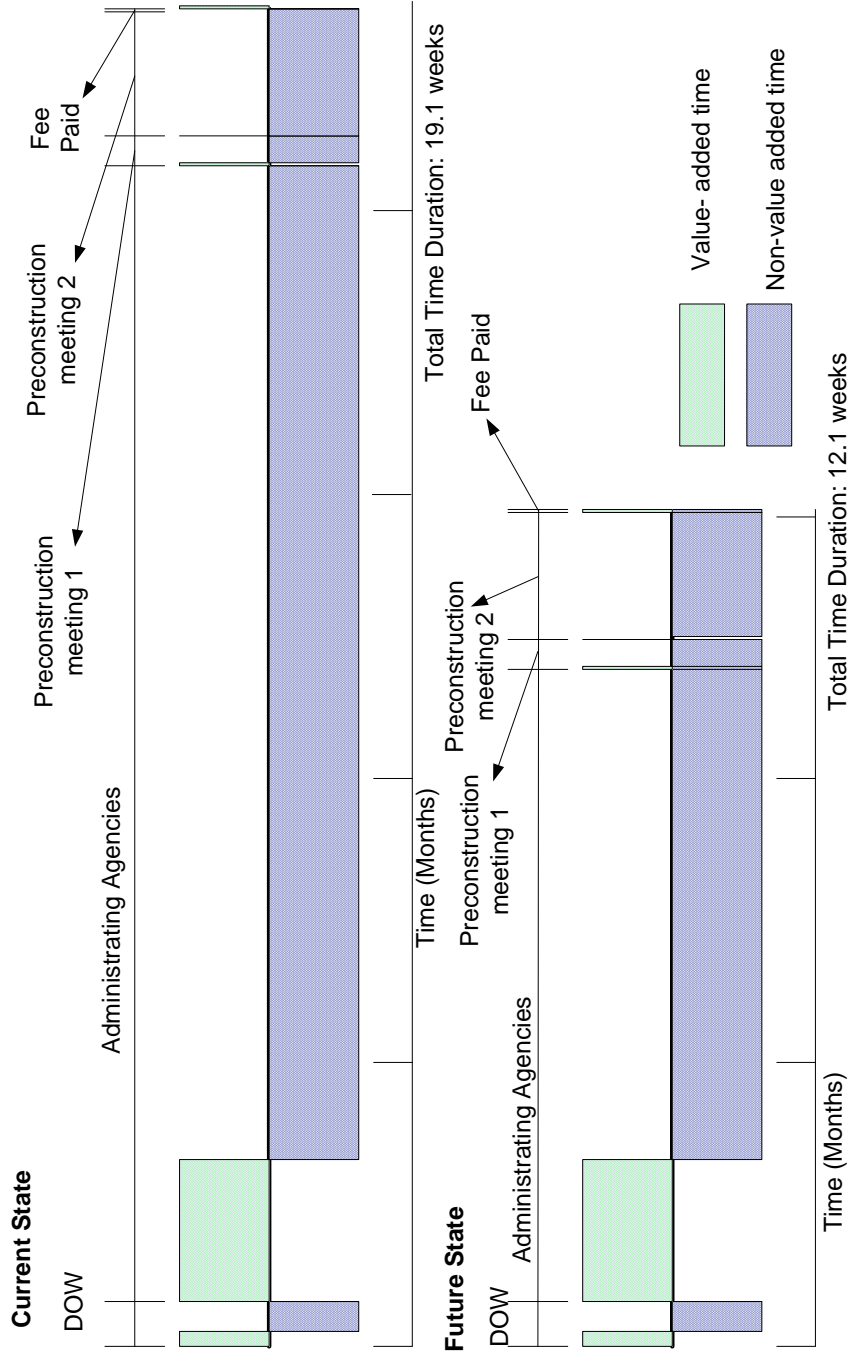


Fig 23: Freeway, bridge & other Project, Proposal-to-Construction, Future State, Timeline

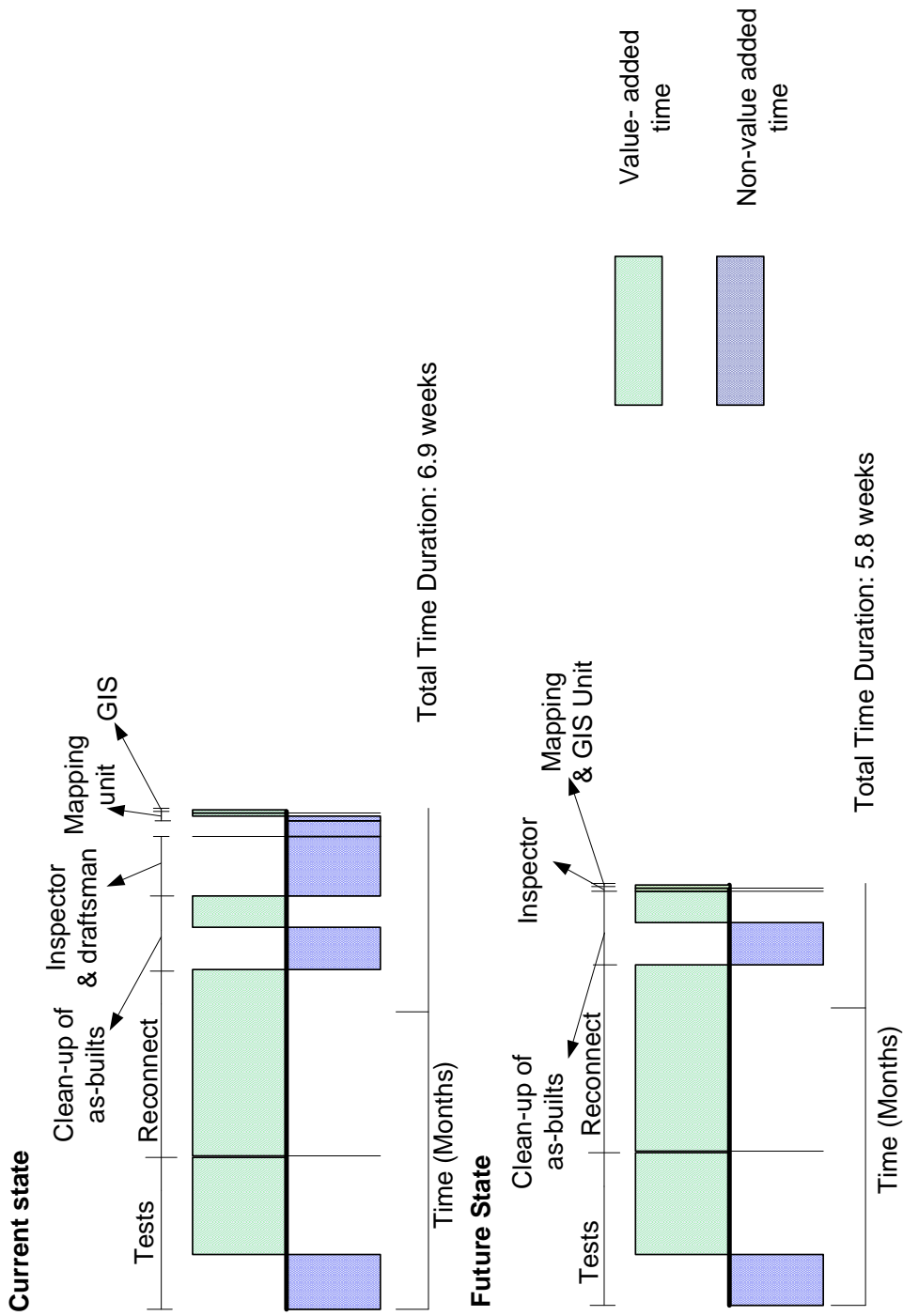


Fig 24: Freeway, Bridge & Other Utility Project, As-Builts to GIS, Future State, Timeline

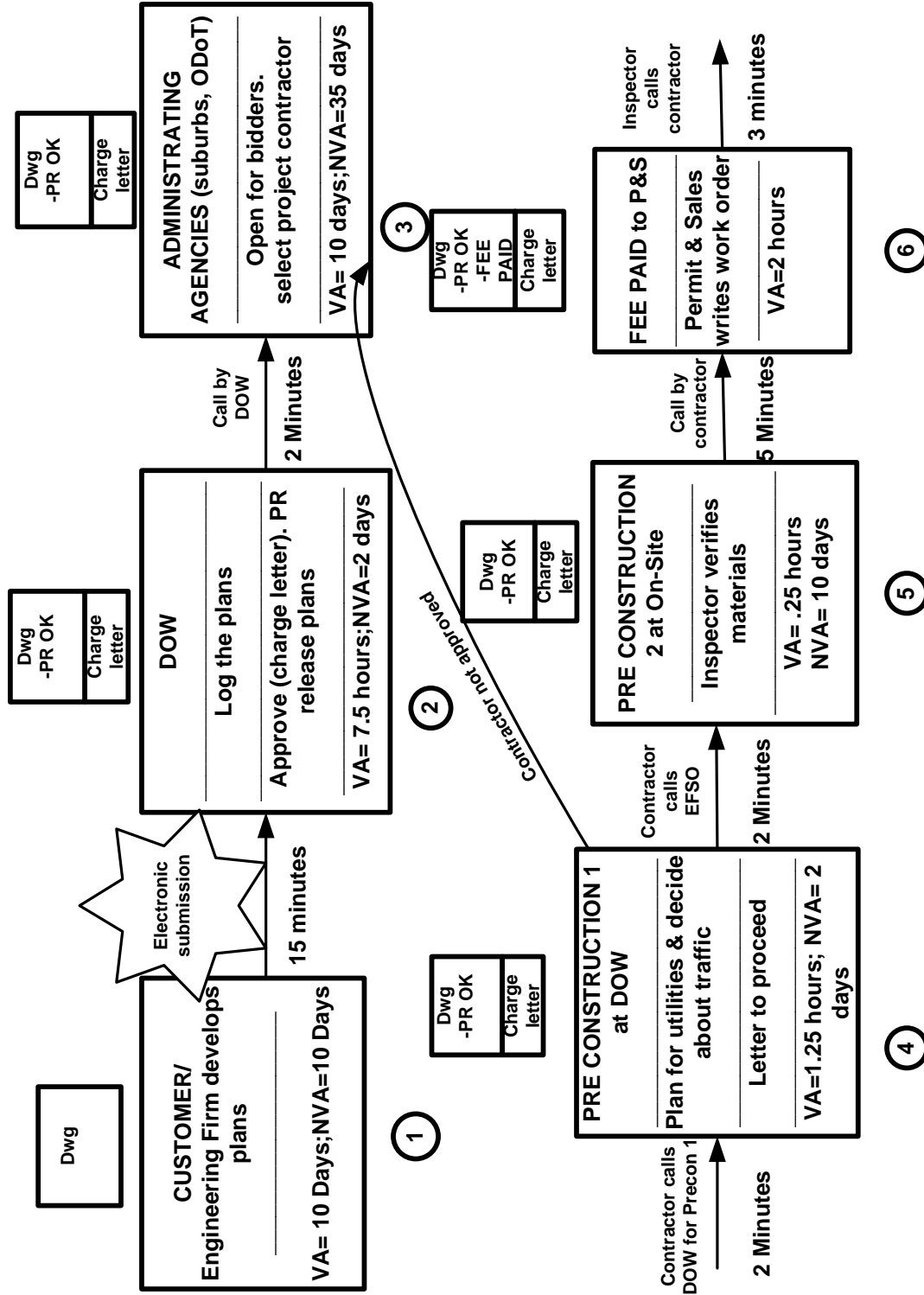
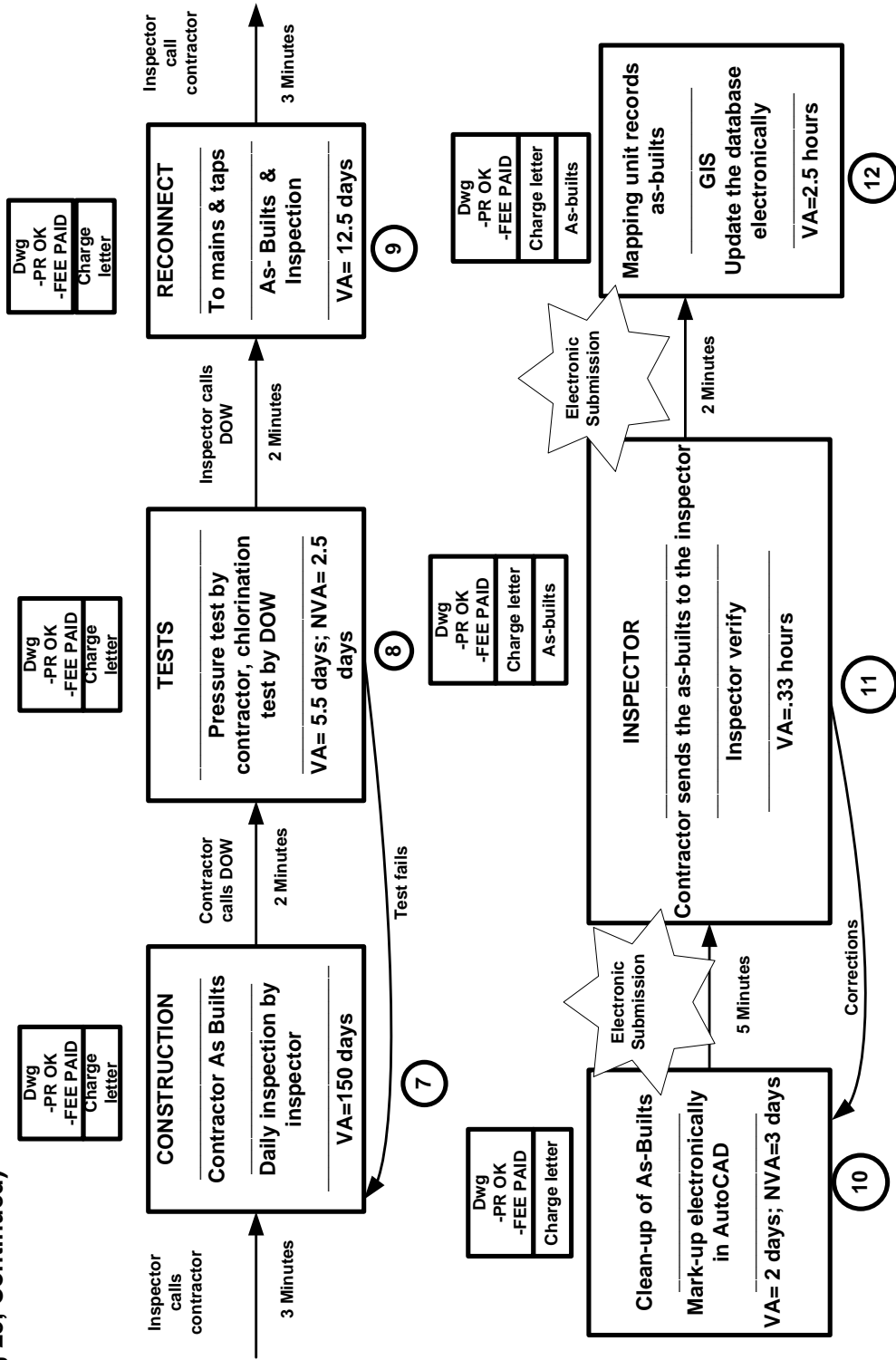


Fig 25: Freeway, Bridge & Utility Project, Future State Map

(Fig 25, Continued)



DISTRIBUTION MAIN NEW INSTALLATIONS & WATER MAIN EXTENSIONS PROJECTS

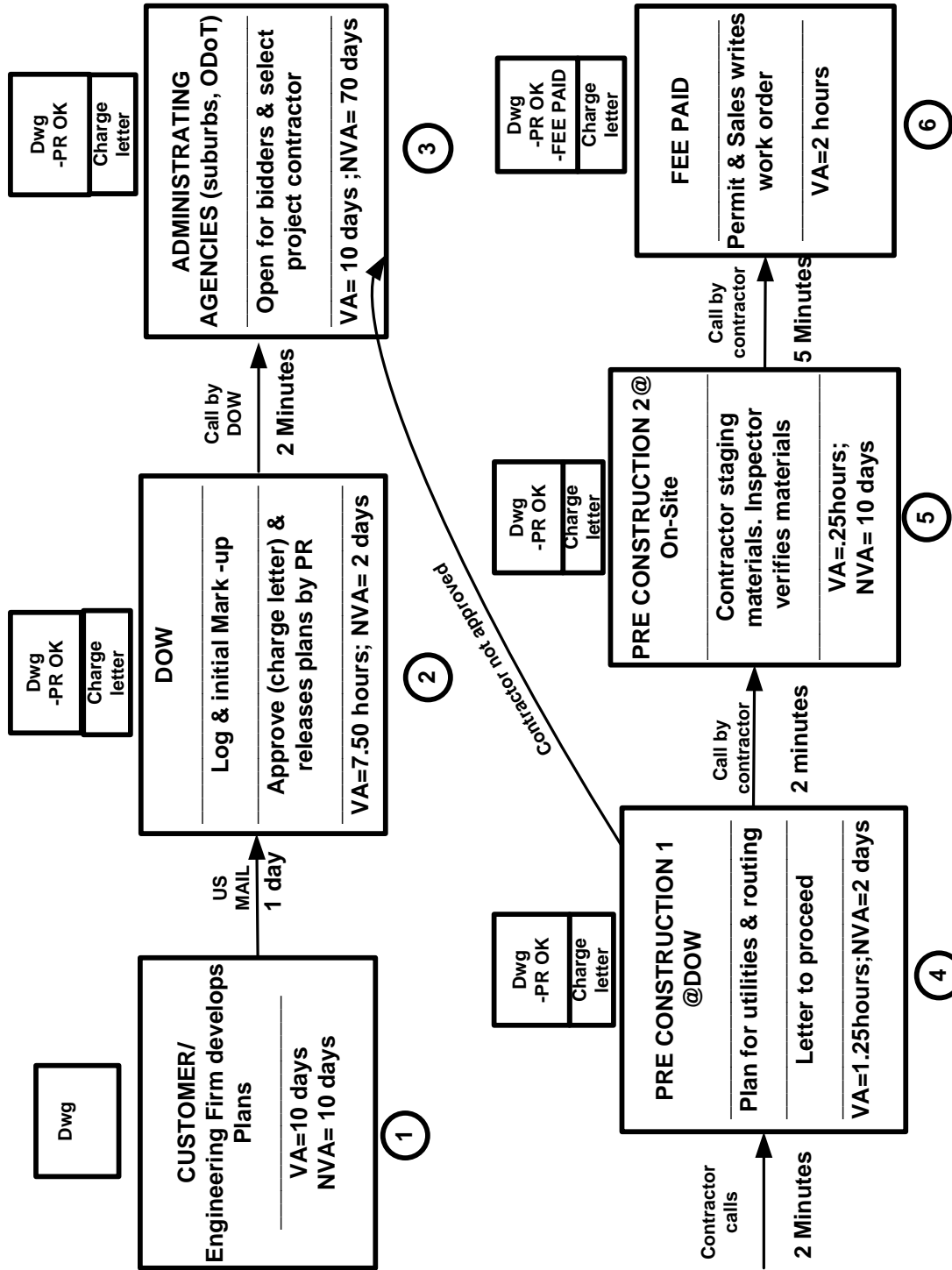
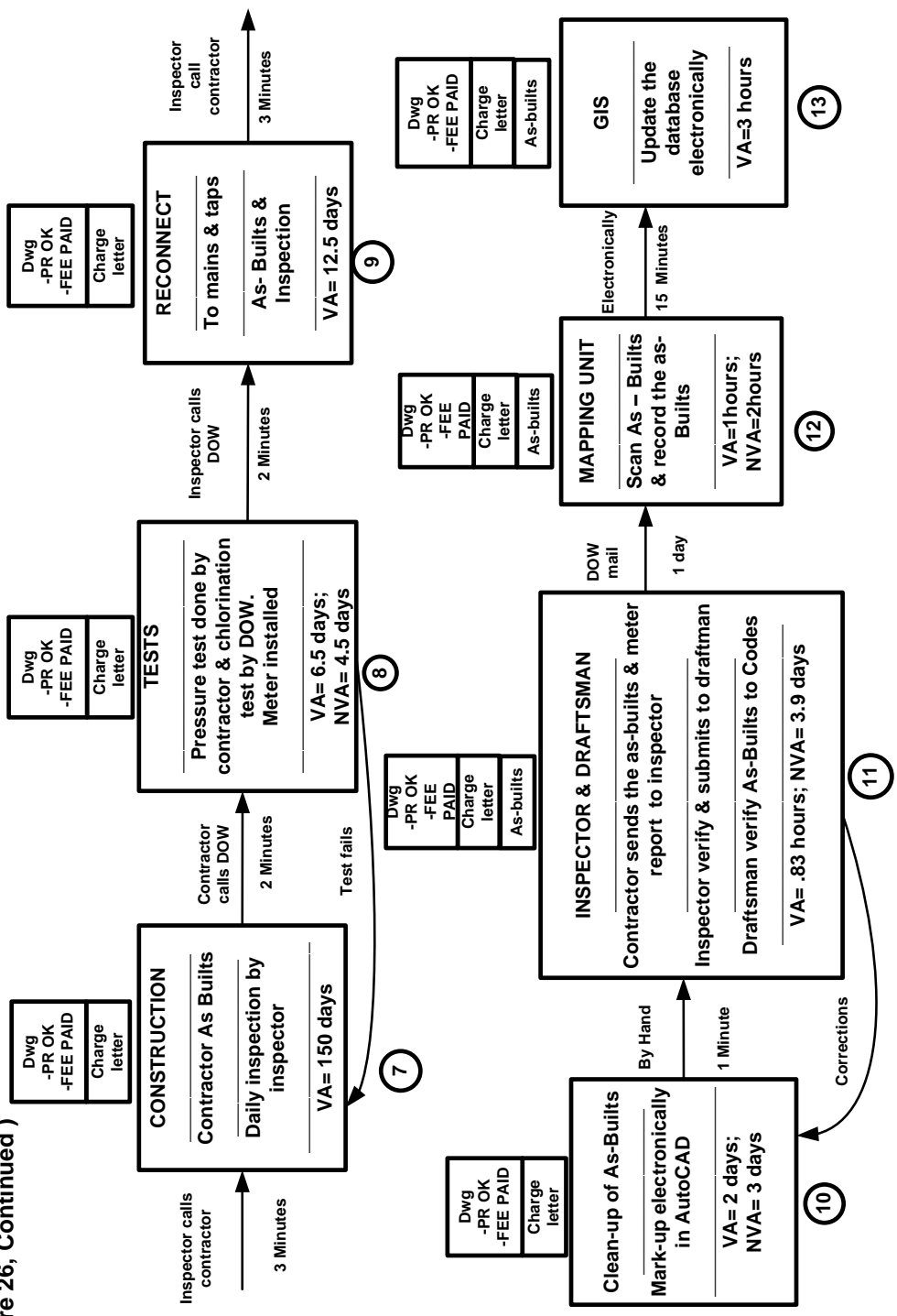


Fig 26: Distribution main new installations & water main extension Project, Current State Map

(Figure 26, Continued)



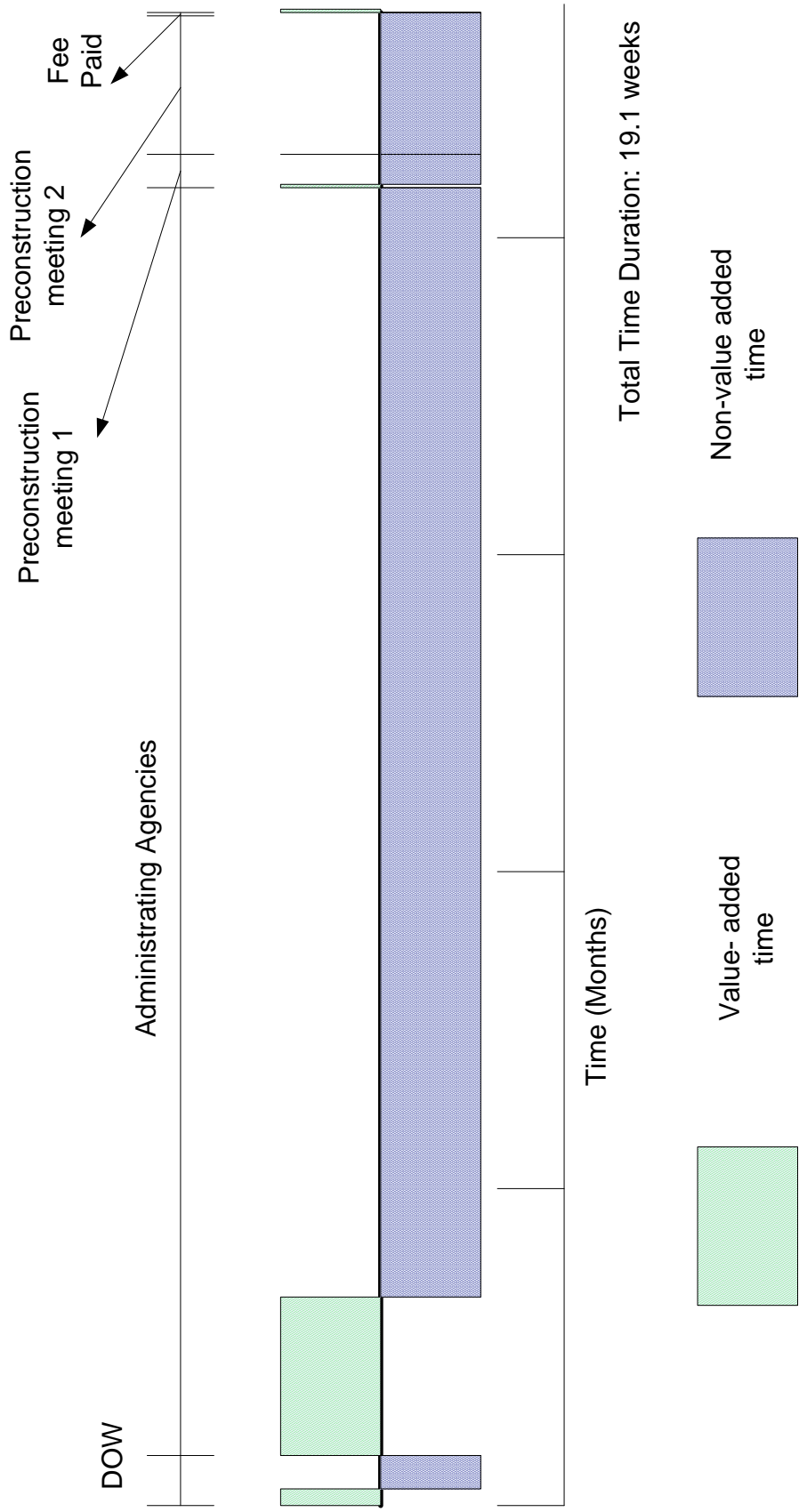
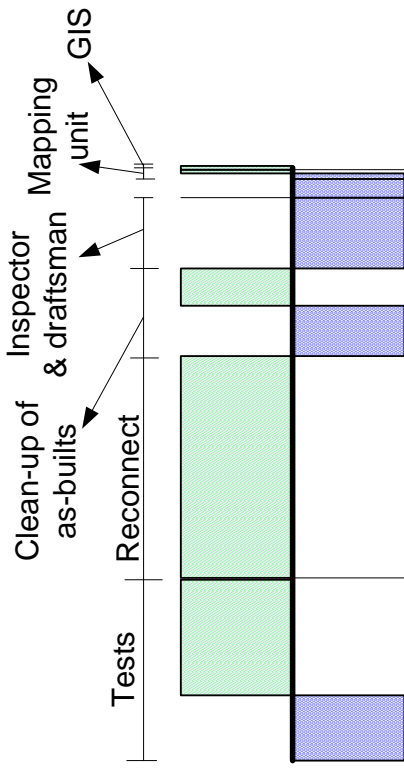


Fig 27: Distribution main new installations & water main extensions Project, Proposal-to-Construction, Current State, Timeline



Time (Months)

Total Time Duration: 6.9 weeks



Fig 28: Distribution main new installations & water main extensions project, As-Builts to GIS, Current State, Timeline

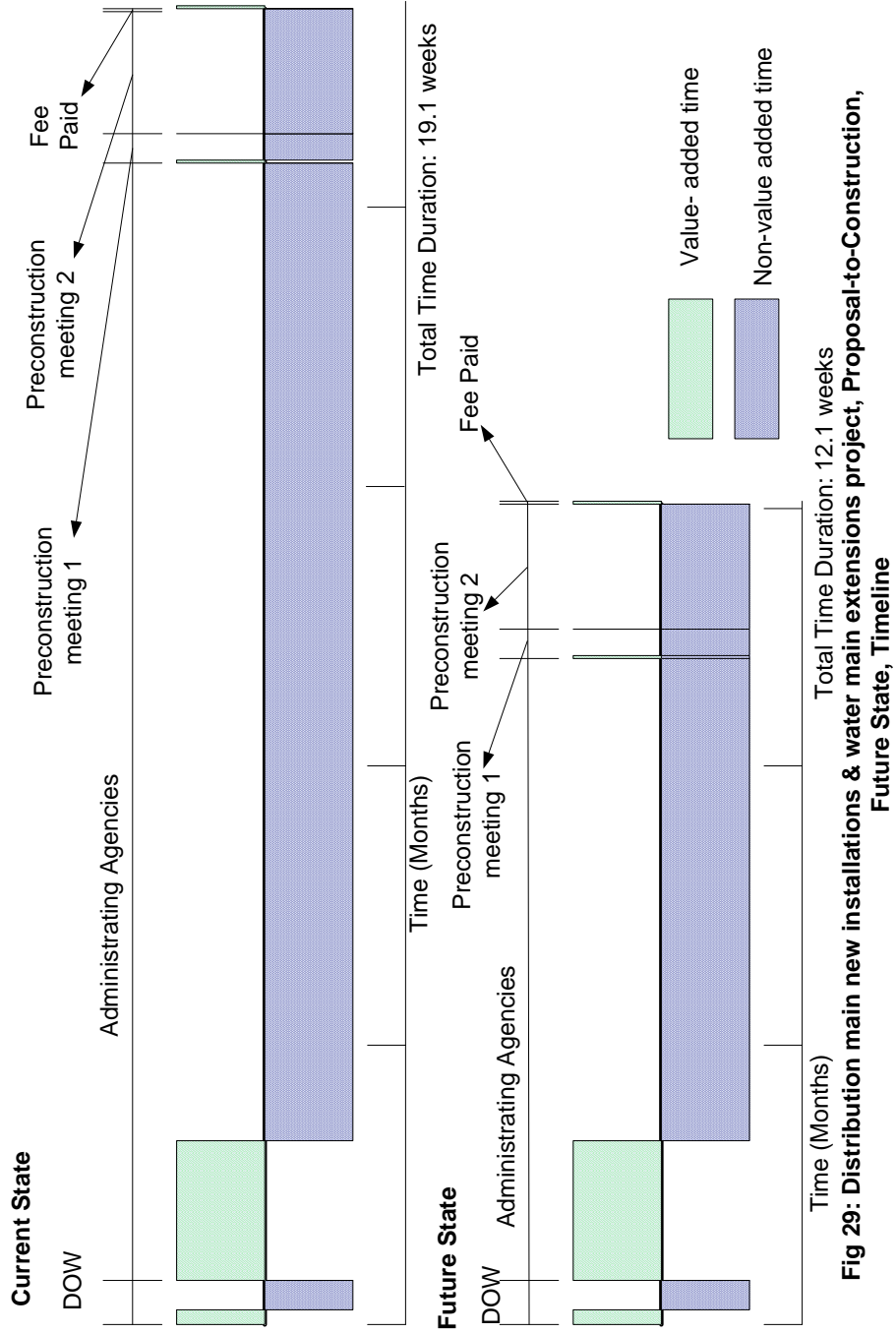


Fig 29: Distribution main new installations & water main extensions project, Proposal-to-Construction, Future State, Timeline

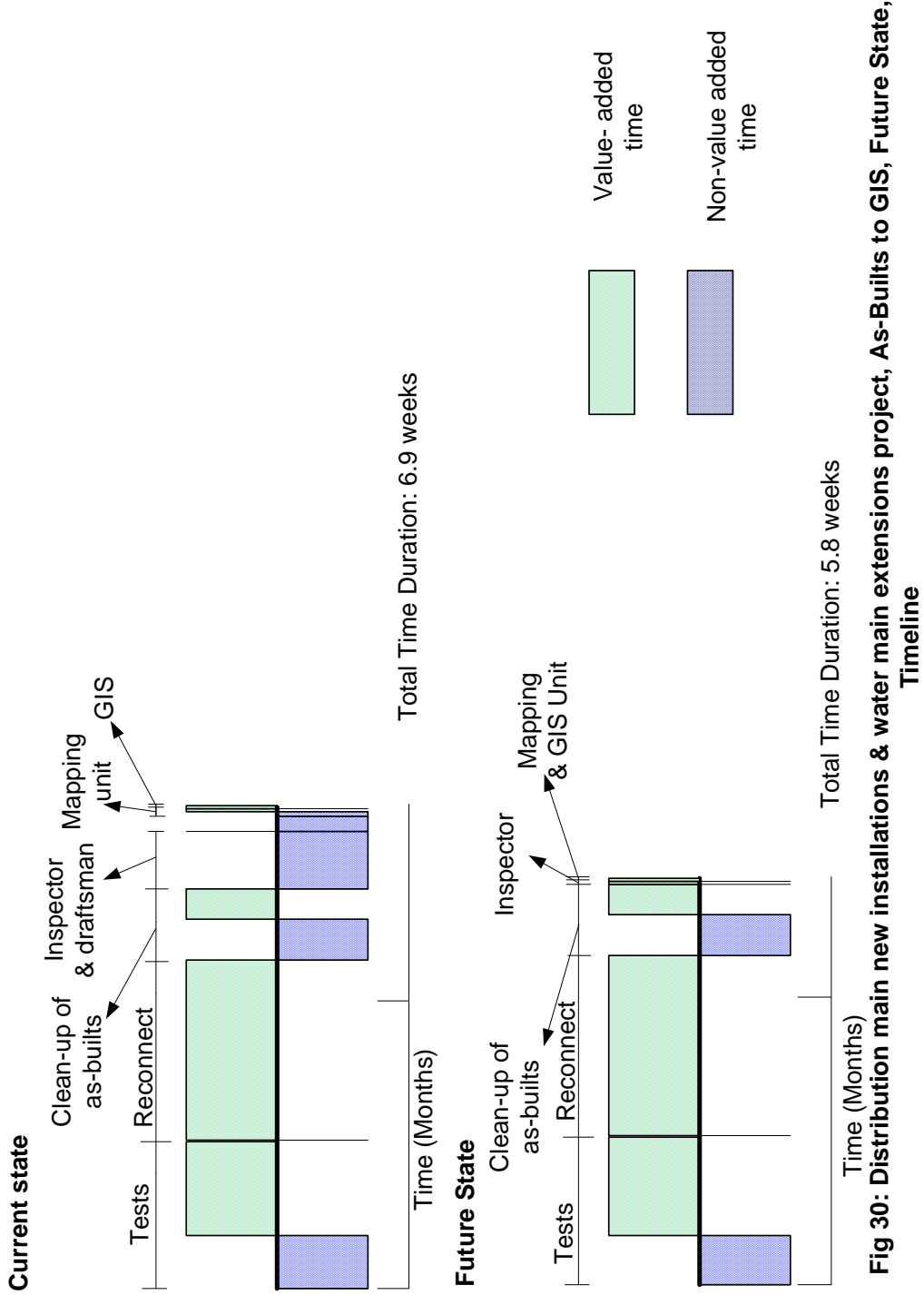


Fig 30: Distribution main new installations & water main extensions project, As-Builts to GIS, Future State, Timeline

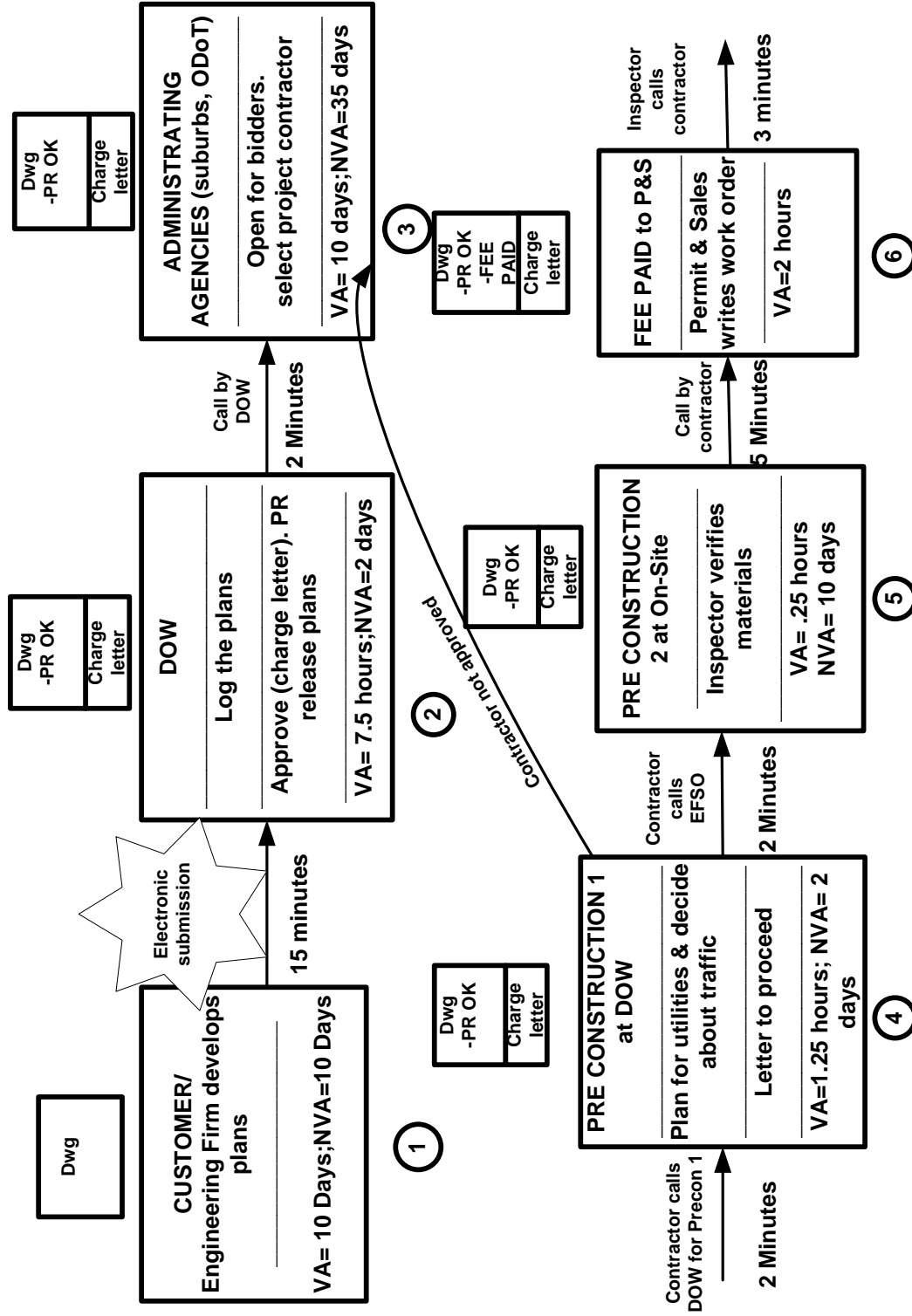
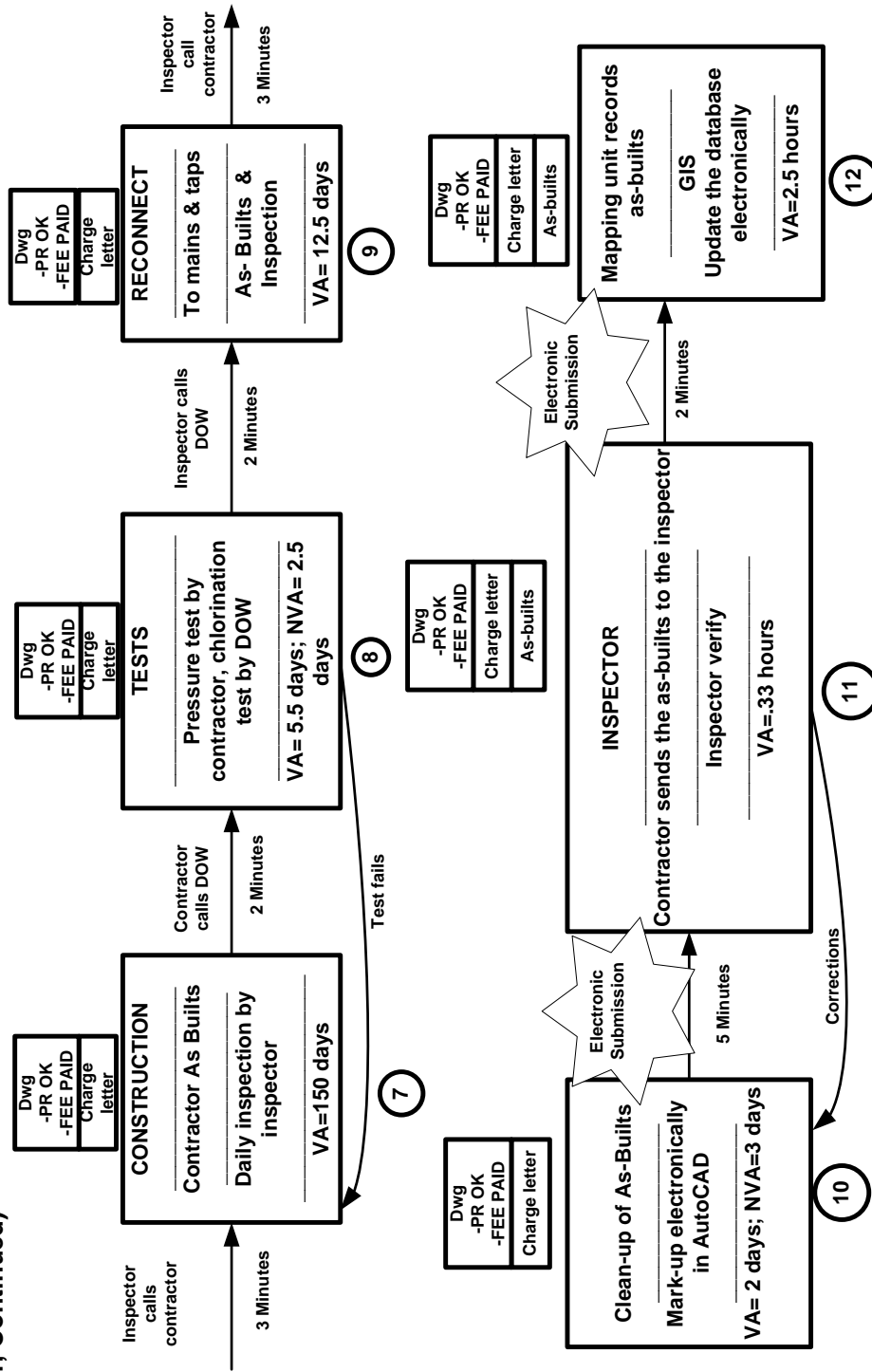


Fig 31: Distribution main new installations & water main extension project, Future State Map

(Fig 31, Continued)



CLEANING & LINING PROJECTS

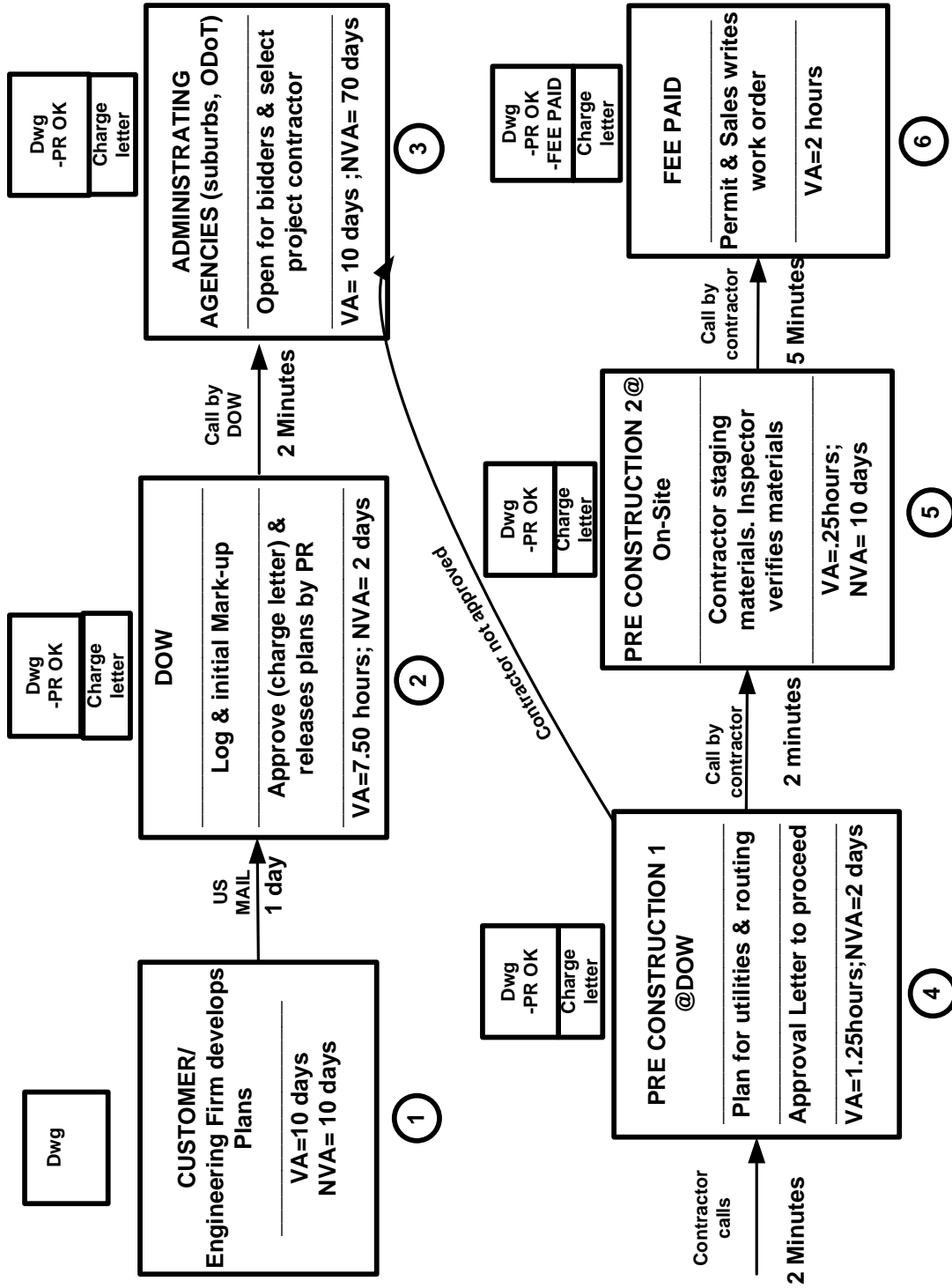
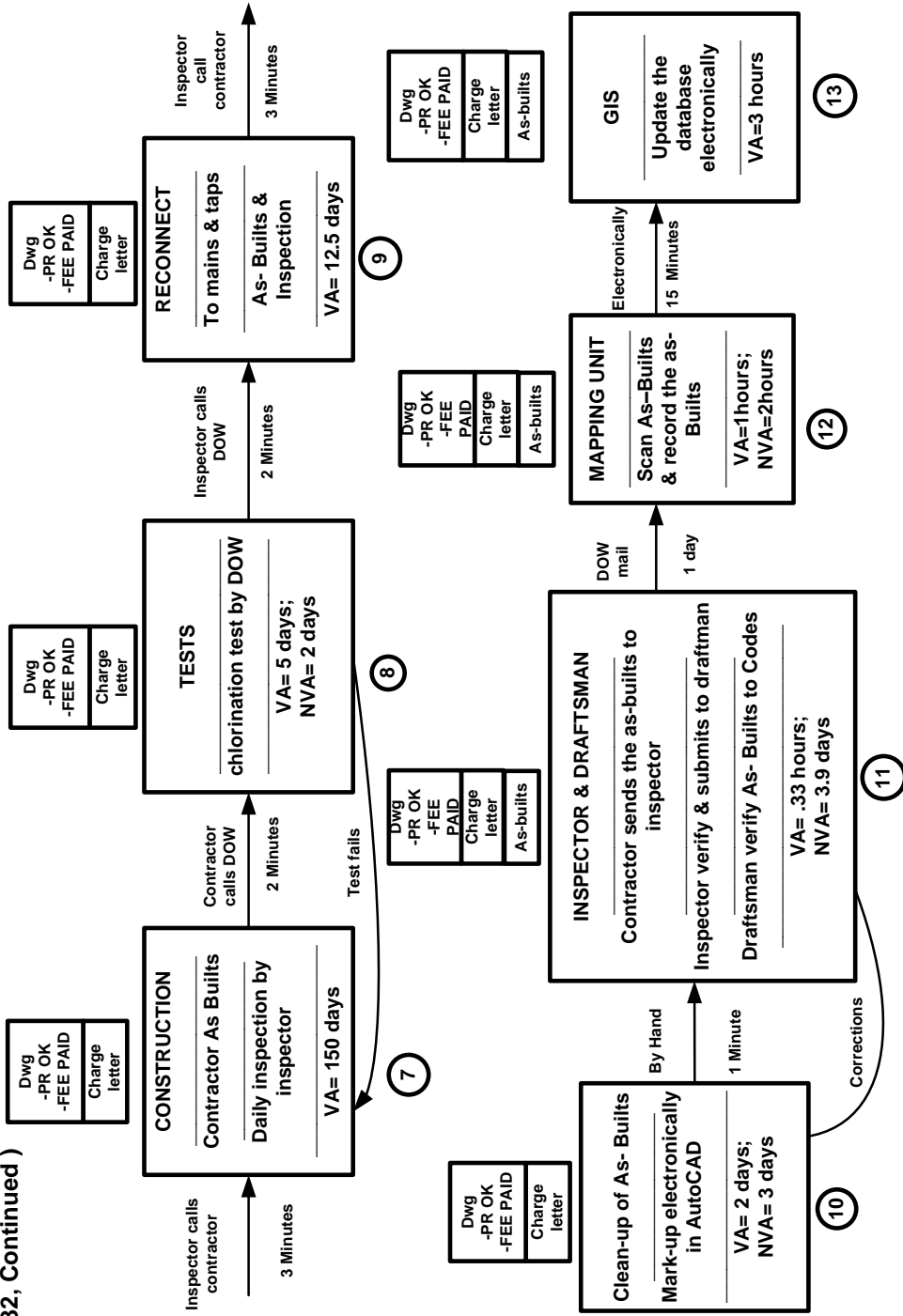


Fig 32: Cleaning & Lining Project, Current State Map

(Figure 32, Continued)



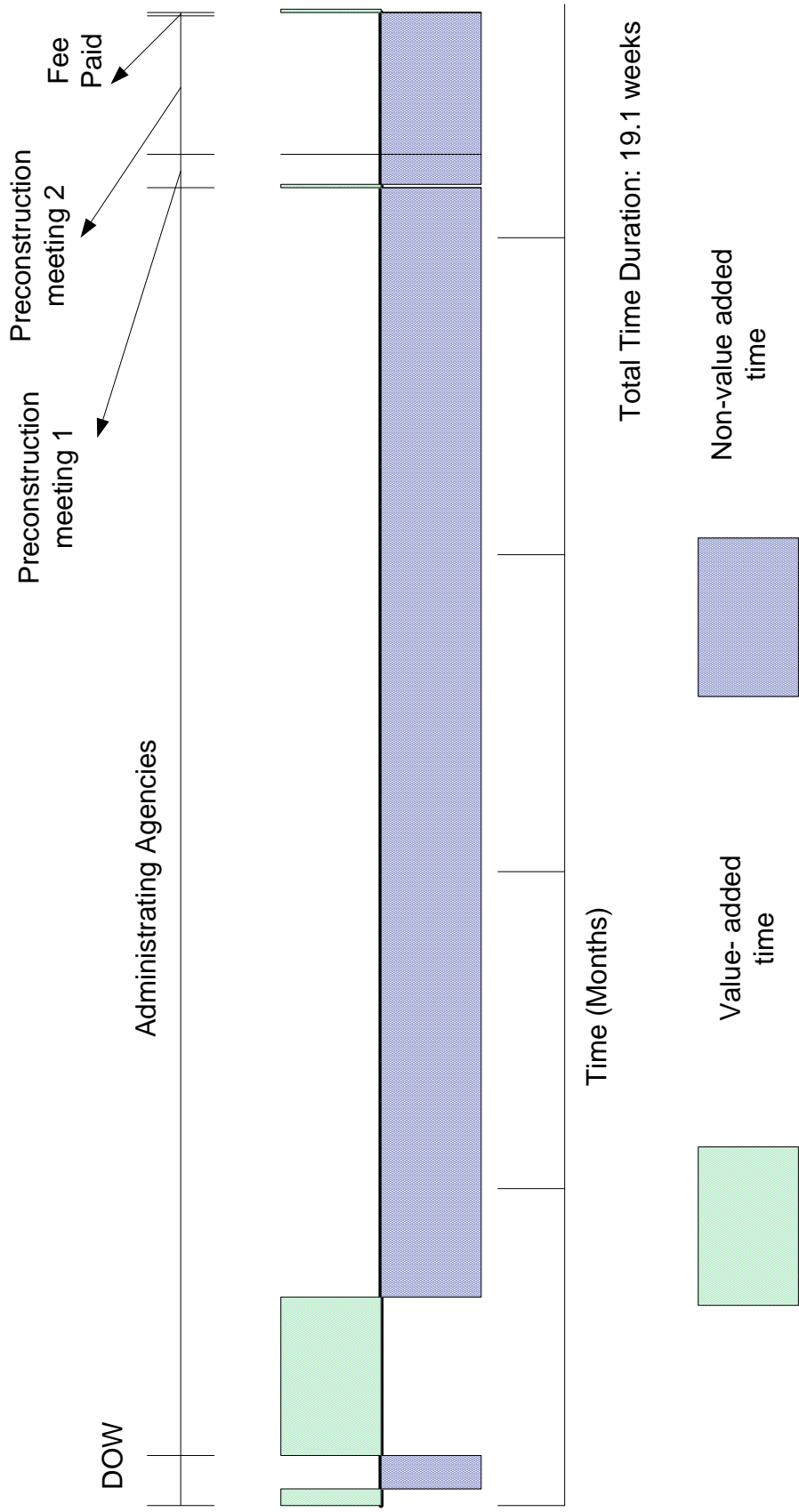


Fig 32: Cleaning & lining project, Proposal-to-Construction, Current State, Timeline

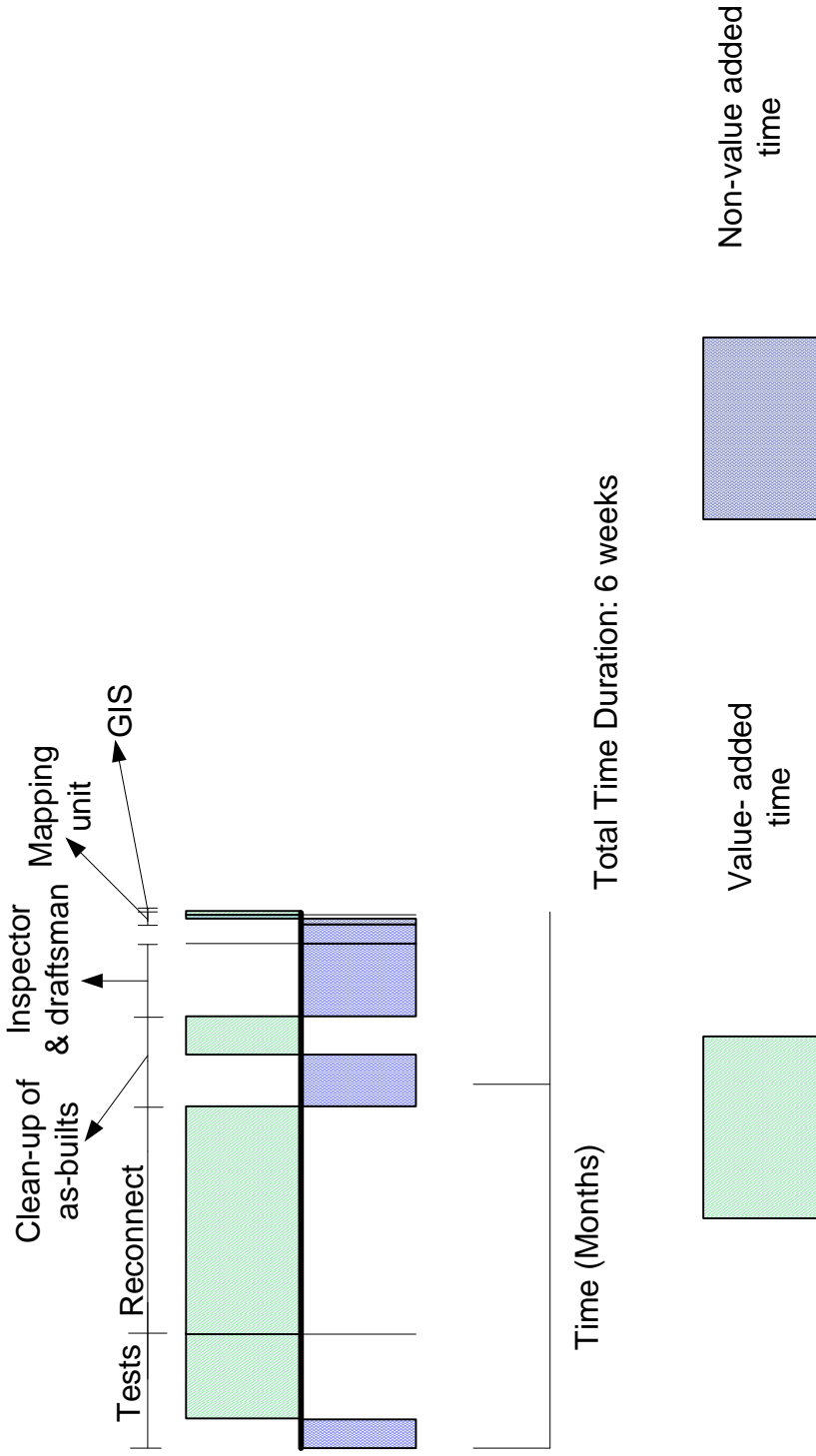


Fig 34: Cleaning & lining project, As-Builts to GIS, Current State, Timeline

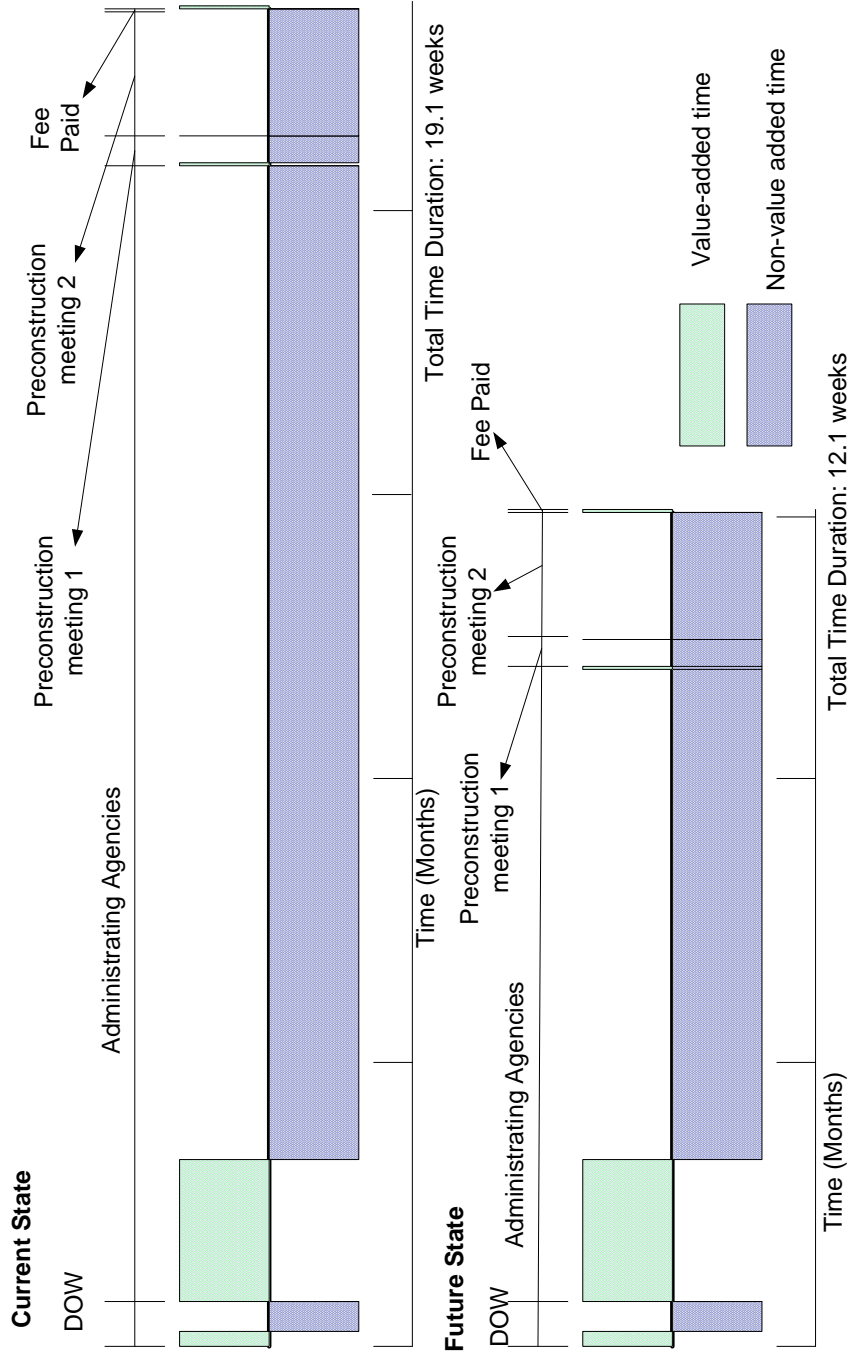


Fig 35: Cleaning & lining project, Proposal-to-Construction, Future State, Timeline

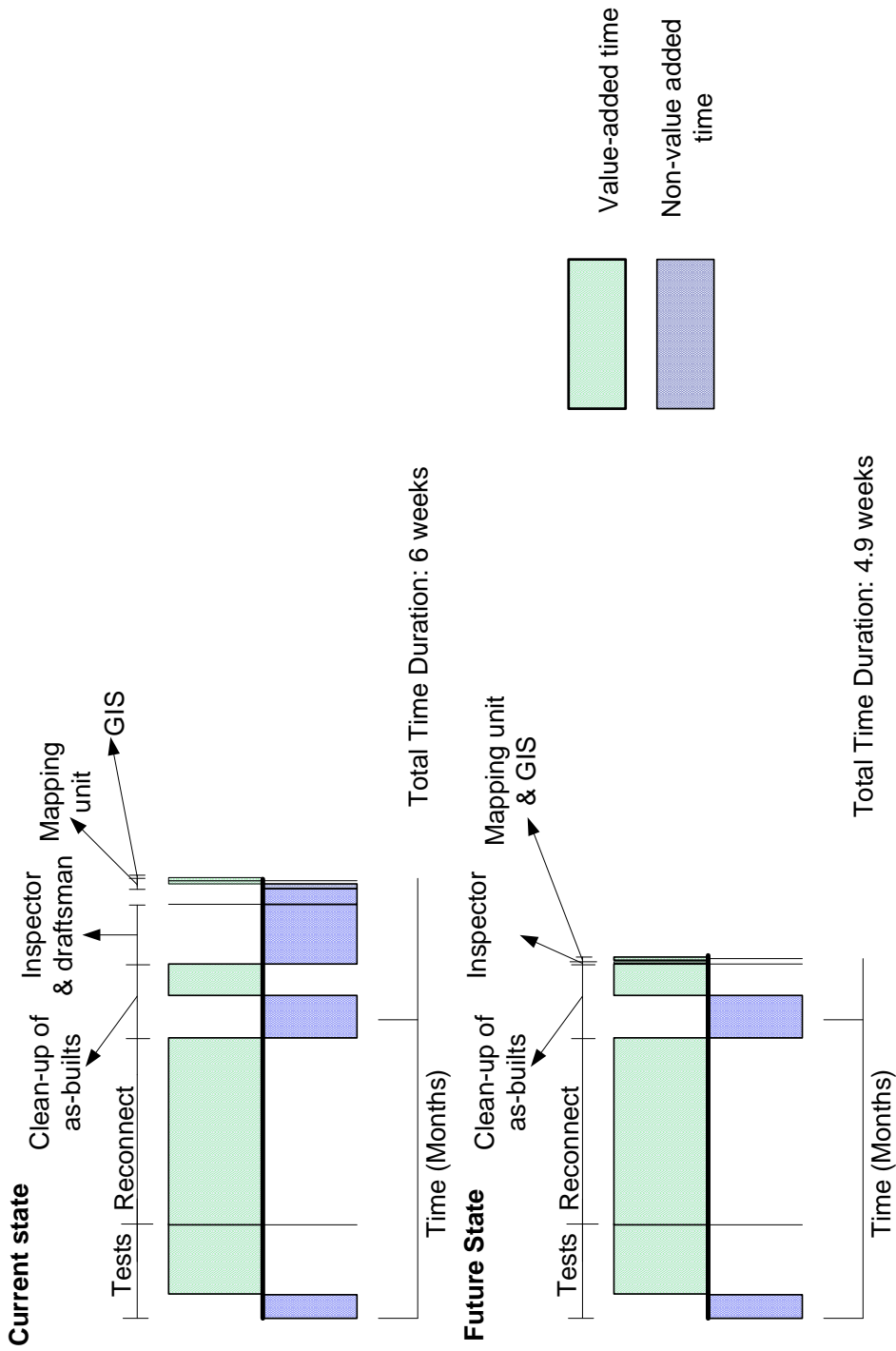


Fig 36: Cleaning & Lining Project, As-Builts to GIS, Future State, Timeline

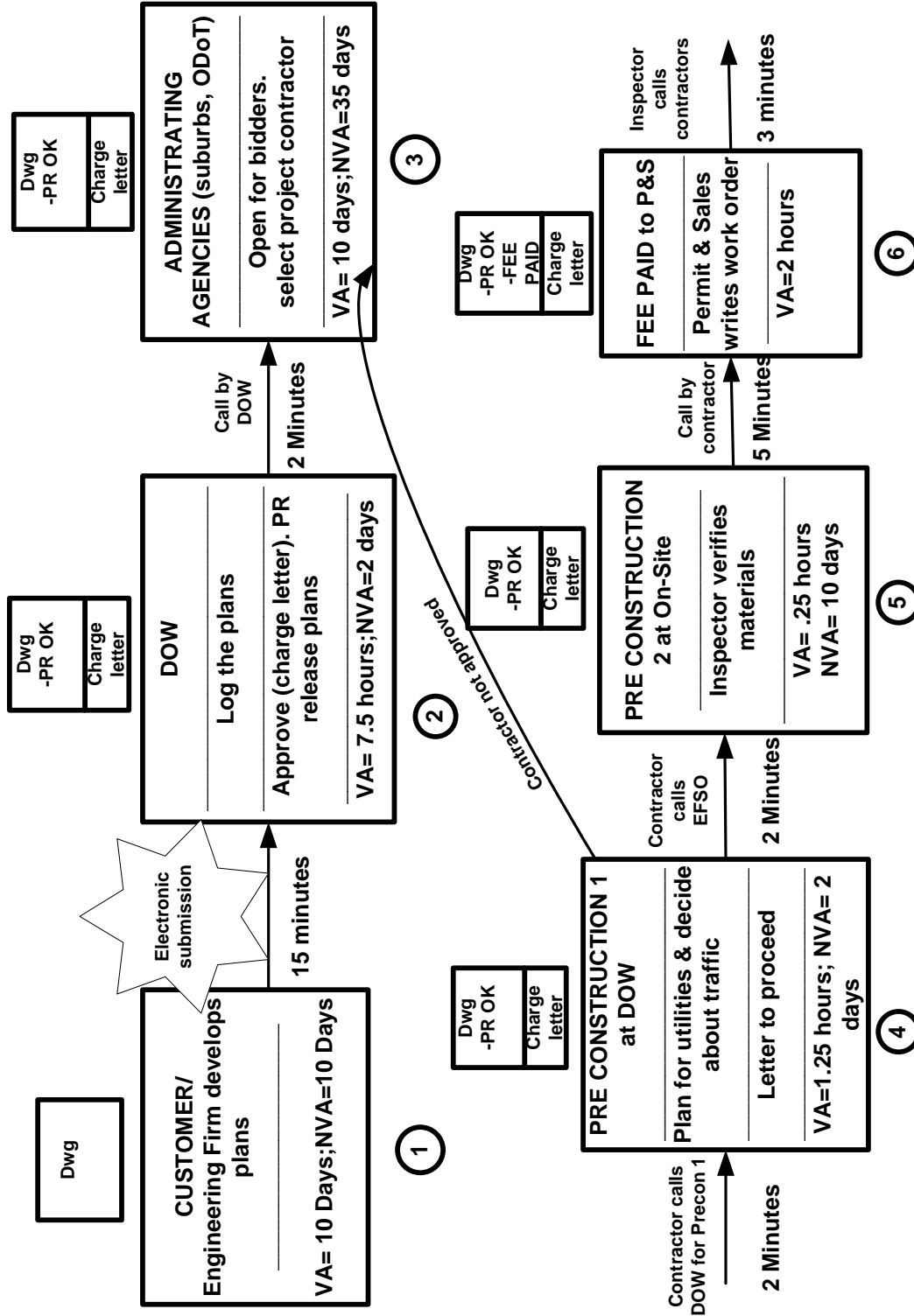


Fig 37: Cleaning & lining Project, Future State Map

(Fig 37, Continued)

