Designing in and for Complex Coordinative Spaces: Interagency Traffic Management and the Evolution of Public Service Work Infrastructure

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Abstract

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Major traffic incidents such as multi-car crashes can spawn countless human and machine processes, as public agencies activate to get to the scene, save lives, move debris, and when possible, get traffic safely moving again. How should this work be organized, and what can make it happen more effectively? Disciplines such as design studies and CSCW (computer-supported cooperative work) study how to create and situate technology systems into varied contexts of use. The idea of "work infrastructure," originally developed by Pipek and Wulf, offers a generative framework to understand how people appropriate and improve the technology systems they use to do their jobs, and offers a useful antidote to simple binaries between "designers" and "users."

However, complex inter-organizational contexts of shared work and technology use, like the inter-agency management of major traffic incidents, are not as well understood by these fields. This is in part because of the complexity of gaining access to the sites of work and decision-making, and of analyzing so many different participants simultaneously. There are great opportunities for CSCW, organization studies, and design research to better understand how different public agencies with different arrangements of technology systems can come together to create shared, multi-organizational systems for managing complex work, such as that of traffic incident management.

In this dissertation, I present one such project, the Virtual Coordination Center (VCC). From 2018-2023, designers and researchers from the University of Washington and software design consul-

tancy Pariveda worked with Seattle-area government agencies to help them improve their coordination during and after major traffic incidents. A large component of this work was the development of the Virtual Coordination Center, a collaborative web-based system that all participating agencies could view and use to share information about unfolding incidents.

As a participating designer/researcher on the VCC, I conducted numerous design and prototyping activities, ethnographic workplace observations, software quality assurance tasks, and many other forms of participation. In this dissertation, I similarly use a wide variety of qualitative analytical and empirical methods to analyze the VCC project. I employ a sociomaterial framing to identify key concepts for understanding how this project worked and how its phenomena connect to larger questions of design, work infrastructure, and coordination.

The resulting analysis has yielded three prongs of conceptual findings: a significant extension and refinement of the dynamics of work infrastructure embeddings in inter-organizational work settings; an analytical framing of collaborative system project stakeholders as coordinative units; and an analysis of designers as stakeholders themselves, using discursive techniques to steward project dialogue and advance conceptual and design goals.

In the Conclusion, I synthesize findings from the three different prongs of analysis, and in so doing, critique and extend the notion of "work infrastructure" originally described by Pipek and Wulf to better account for inter-organizational system use. In short, while work infrastructure is characterized in terms of its complexity, pervasiveness, and flexibility, conceptual work around this idea doesn't fully take into account the longer-term infrastructural processes of an organization. The *de facto* work infrastructures that get embedded over time–those that are actually within the reach and understanding of real users–don't behave the same as the formally documented versions that organizations manage. These "holographic" work infrastructures are moving targets. Moreover, in inter-organizational work contexts where there is no single locus of analysis, design work will visibilize specific parts of cross-organizational influences and information-sharing, and make them susceptible to shaping and changing.

I further examine the "point of infrastructure," a key moment in the development of work infrastructure that can lead to "design-in-use." I identify, based on the previous findings of the disserta-

tion, processes that can inhibit or mask points of infrastructure, particularly in inter-organizational collaborative projects; suggesting that designers and designer-users may have to look more broadly and deeply for these potential points of infrastructure, and be willing to unpack apparent smooth functioning to do so.

All of these conceptual findings are linked to specific recommendations for researchers in designers in similar spaces.

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ACKNOWLEDGMENTS

The list and details of thanks that are in order could surely exceed the length of this dissertation. But I will keep it brief.

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DEDICATION

To Jordan, with whom I boldly go

Chapter 1

INTRODUCTION

A major car crash on a busy highway is a violent, frightening, and extremely complex event. Fear, injury, destruction, and even death can create a gruesome spectacle splashed across the news. Major thoroughfares can grind to a halt for hours. Damages to infrastructure can lead to long-term closures and great public expense. This moment of crisis, like other kinds of incidents that have major impacts on highway traffic, can spawn countless human and machine processes, as public agencies activate to get to the scene, save lives, move debris; and when possible, get traffic safely moving again. Beneath the ground, loop sensors detect the sudden slowdown of traffic and send notifications to traffic engineers. In the air, traffic cameras stream the crash into control centers miles away. On the road, witnesses start calling 911 and posting worried questions to social media. The 911 call takers work with their dispatchers to send the appropriate combination of roadside assistance, medical aid, fire suppression, traffic control officers, and investigators to the scene.

Once on scene, each of these parties communicates on a regular basis to their chain of command, while addressing urgent/emergent issues, and taking numerous possible decision paths into account while planning the remaining work to be done. If the crash is severe enough, responsible on-scene workers coalesce on a strategically placed location to establish incident command. The sudden change in traffic patterns could also create a glut of travelers for nearby transit lines, or require the closure of high-capacity bus lanes, which can throw off transit planning and management for hours. Public information officers prepare to join the fray, wading through varying degrees of information and misinformation to figure out how to convey the right messages to the right people. Other public agencies such as utilities agencies, and even private businesses such as towing companies, may also participate in these efforts. Potentially dozens of people, and hundreds of software and hardware systems, come together to make sense of what is going on, and orchestrate complex and rapidly changing task dependencies, so that the situation can be resolved as quickly and safely as possible.

Once the incident is resolved and traffic is flowing normally again, after-action reviews can

begin. Participating parties gather their own systems of data capture and analysis to examine what happened and whether any useful lessons can be learned for future incidents (or even, ideally, to prevent future incidents). Some major incidents are significant enough that participating agencies hold a shared after-action review. Each brings their own data, gathered according to their own standards and processes, from their own point of view and attending to the signals they find important and useful. From this, they try to figure out what worked well and what could work better. Rarely, the analytical output of the incident can shape the physical infrastructure itself, if changes are made to the roadways, signage, or even in policy, if deficits in any of these were found to contribute to the severity of the incident.

Managing incidents in real time, and analyzing them in post hoc debriefs, means trying to get a handle on interactions between and among humans, policies, and technologies with compounding, often nonlinear impacts and consequences. Like air traffic controllers, who are "struggling to create order out of disorder" [157], highway traffic management is a continuous effort to structure and analyze an unstructured flow of physical and informational phenomena. This presents a number of fascinating and consequential sociotechnical puzzles. One important category of puzzles has to do with how people try to work together effectively as an operational community, when the technology systems used to carry out incident tasks–the work infrastructures [117] of traffic incident management that support the operation of critical physical infrastructures–vary so significantly, often with poor or no interoperability.

1.0.1 Situating the Research Question

Human-Centered Design (HCD) and Computer-Supported Cooperative Work (CSCW) are fields that have studied how to create and situate technology systems into varied contexts of use. Along with infrastructure studies, which seeks to understand the often long-lived systems that enable many kinds of work, they have helped practitioners and social scientists better understand the needs and dynamics of technology users in shared work situations. However, complex inter-organizational contexts of shared work and technology use, like the inter-agency management of major traffic incidents, are not as well understood either by CSCW theory or by design or infrastructure studies [157]. They are, after all, quite structurally complex, and logistically challenging to study for

sufficiently long periods of time. The on-the-ground operational dynamics, infrastructural configurations, historical relationships between organizations, and public and legal commitments that surround these settings can make their project decisions–and the consequences of those decisions–hard to understand, especially from the outside. It is often difficult for researchers and designers to gain access to the inner workings of such organizations, as they can be under public accountability measures that can make them cautious about giving researchers unfettered access. Yet this vast array of components, practices, jurisdictions, and participants touches upon a huge (and often underappreciated) part of the shared life of cities, and offers countless opportunities for studying the creation and use of collaborative technology across organizations. How might our discipline make better sense of these design contexts, and what do their differences have to teach us about design theory and practice for shared technology use?

The work presented here is a distillation of my extensive and long-running work as an ethnographically oriented action researcher in the Virtual Coordination Center (VCC) project. In this project, University of Washington designer-researchers worked with multiple public agencies and professional software developers to create a new shared system to enable improved traffic management work in the Seattle, Washington region. Exploratory work began in 2018, with initial software development commencing in 2020, and completing in late 2022. The resulting Virtual Coordination Center is a web-based system that allows these different agencies to share information around significant traffic incidents, and represents a new technical and organizational approach for their shared efforts.

The VCC is intended to facilitate effective coordination and information sharing between agencies that manage traffic and congestion in the Seattle area, particularly during major traffic-impacting incidents. Following its operational deployment in early 2023, it is now in regular use among its participating agencies. It has recently begun expansion to several other jurisdictions and has received programmatic state funding. It has also been appropriated by its user community for a slightly broader set of use cases, including planning major road closures and major public events likely to have traffic impacts, like major sporting events or music performances.

Codesigning this system required considerable effort in analysis, design, technical integration, policy-crafting, and relationship building. My experience in these efforts spanned both significant time (2018-2023) and many different project management and research roles. While this experience

was varied and heterogeneous, it provided the basis for this dissertation and the connections I make to other theoretical and methodological challenges in inter-organizational design. I describe the project, my experience with it, and the VCC as an interface, in greater detail in Chapter 3.

Armed with this background and experience, I intend to pursue the following primary research question: *How can designing collaborative systems help interdependent public service stakeholders innovate their shared work?* Interdependence between actors creates complexity, both for the shared work itself and for researchers analyzing it. However, it is also, as I will discuss more extensively in the Literature Review, a basis for defining different forms of shared work (commonly delineated as "coordination," "cooperation," and "collaboration"). Treating these concepts directly will allow me to connect a framework of coordination to the way stakeholders are modeled in large projects, motivated by work in fields like political science and organizational studies. This conceptual and practical connection between coordination in complex inter-organizational work contexts, and what counts as a "stakeholder" in that coordination, helps to fill gaps between the [theoretical] *study* of coordination and the design of actual *systems* for coordination.

The RQ also specifies a certain type of stakeholder: the "public service" stakeholder. While I anticipate the findings of this dissertation can be extended to other kinds of work, I retain this level of specificity deliberately. The particular commitments and constraints of public service work color the relationships between the agencies, the policies that govern their interactions, and even how they organize their work in reference to technology systems. Further, highlighting these particularities will enable CSCW and infrastructure and design studies to approach other government-oriented projects more effectively, which I believe is a critical need for these disciplines.

The VCC system "lives" in a number of work settings, and alongside many existing traffic management technology systems and practices which it must integrate into, or at least avoid destructively conflicting with. Effectively harmonizing this new system with these historical configurations, in terms of systems and practices, is perhaps *the* challenge for the ongoing success of the VCC. It is also a chronic practical challenge for effective inter-organizational collaboration and shared action, and for the design researchers and professionals who aim to support them. In this dissertation, I will help to address this challenge by extending and critiquing the concepts of *work infrastructure* and *embedding*, two core ideas in CSCW and infrastructure studies that wrestle with the fitting of old and new. The VCC is not only a specific system created to help users coordinate

traffic incident/congestion management work, but it also operates in several different work places, and its use as a collaborative and distributed system is conditioned by how people relate to the many other technology systems that support traffic management work. What is currently missing in the account of work infrastructure, and which this dissertation seeks to advance, is a focus beyond intra-organizational work infrastructure. When work and systems traverse organizational boundaries, how they work and how they can develop changes in profound ways.

Innovation is also a part of this research question, and can mean a variety of things; at times, it can be quite a loaded term in design research. However, like work infrastructure and the embedding of infrastructures, it fundamentally has to do with change in reference to existing systems and practices. The context provided by prior system use–the "embedding" of work infrastructures–both scaffolds *and* obstructs new approaches like that represented by the VCC. This means that the VCC project can be seen as not just a design project, but a lens or probe into how innovation happens in this kind of setting. The VCC can be a replacement, a complement, or a hindrance for the use of these other work infrastructures. For this reason, a part of understanding how "innovation" happens through collaborative system development requires a deep dive into the different work infrastructure environments it must be situated into.

My dissertation builds on an existing body of work connected to the VCC. This includes three publications in CSCW, the conference for Computer-Supported Cooperative work and the primary disciplinary home of this dissertation. In these works, my colleagues and I explored different parts of the VCC project: its settings (traffic management control centers), its project management, and its use of policy documents in the design process. I discuss these works in more detail in the Literature Review.

1.1 Structure of the Dissertation and Summary of Contributions

The rest of the dissertation will proceed as follows. Chapter 2 is the literature review, where I will first briefly explain some of the VCC's relevant domain context, and how CSCW has interacted with the domain. I will then more deeply treat the key concepts of work infrastructure, coordination, and interdependence; and will conclude by preparing for the Methods chapter by examining how "design" has been used outside of our typical "design" fields to describe the kinds of actions implicated in the VCC's longer-term project. Chapter 3 presents a more detailed description of

the VCC project as a field site and my forms of engagement with it, and a brief explanation of the VCC interface and components. Chapter 4 is the Methods chapter, where I will first describe how the VCC project *itself* was undertaken, in reference to other methods that attempt to blend ethnographic analysis and data collection with design efforts. Then, I will detail the combination of qualitative methods I used to structure, curate, and analyze the large and heterogeneous dataset generated during the project, and the set of focused followup interviews I conducted in early 2025. Chapter 5 is an extended narrative of a hypothetical major traffic incident, synthesized from findings from my 2025 interviews. It serves a few purposes: to provide greater detail about the kind of work the VCC's operational stakeholders do over the course of a major incident, the complexities and stakes of that work, and how stakeholders generally interact with each other; to bridge between the Methods chapter and the analytical chapters; and to demonstrate one example of a "co-creation" activity (creating a rich scenario narrative) as a shared accomplishment between me and the participants.

Chapters 6, 7, and 8 are each dedicated to answering a different aspect of the research question. In Chapter 6, I will extend the idea of work infrastructure "embeddedness," particularly in the context of inter-organizational work. Embeddedness is a concept core to infrastructure studies, but how it happens, particularly in inter-organizational settings, is underspecified, and this chapter offers some new ways of understanding the processes of work infrastructure system embedding. This is critical for addressing my research question, because the VCC participants' prior contexts of system use significantly shape how a new system like the VCC can be developed and introduced. In Chapter 7 I will examine the notion of a "stakeholder" in an inter-organizational collaborative design setting, connecting the idea of a stakeholder as a coordinative *unit*, rather than an individual person. This will help to explain and model the influences of collaborative systems on their broader inter-organizational coordinative settings. In Chapter 8, I will turn the ethnographic lens on the design team itself, examining how we ourselves acted as stakeholders. I will show how we used discursive techniques to navigate the VCC's complex design space in partnership with the operational stakeholders. Throughout the analytical chapters, I weave in examples of specific VCC components whose development–or attempted development–illustrate the phenomena I discuss. I will conclude with some implications and outlines of further work for selected concepts, and synthesize these ideas into a potential program for future research and design work.

The VCC project has a considerable amount of specialized vocabulary and jargon. While I have attempted to explain each term inline, the Glossary (9.4) after the Conclusion also provides definitions and common abbreviations.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

To understand the VCC project and how I hope to approach it intellectually, I draw upon work from several fields. First, I will trace the path of my own intellectual engagement with the project, in the form of my past publications, and how they established some of the ideas I build upon in this dissertation. I will then explain a bit of the domain context of the VCC project: intelligent transportation systems, civic technology, and briefly how CSCW often engages with similar settings and domains (when it does).

After setting this groundwork, I will engage with a few key ideas. I will begin with the notion of "infrastructure" as it has generally been employed in CSCW. I will then look at a particular type of infrastructure, "work infrastructure," and some of the key work that comments on it in ways most pertinent to my project. In so doing, I will describe some of the ways work infrastructure, and the complexities of integrating embedded infrastructures, interact with social and organizational development of their users and stakeholders in collaborative practice. This begins to establish a methodological posture of taking implementation and system design seriously, which I will take up in greater detail in the Methods chapter.

After this more grounded sociotechnical and infrastructure-oriented discussion, I will spend significant time analyzing two key concepts, "coordination" and "interdependence," and how they are treated in relevant literatures. These two notions can, in different pertinent fields, be treated as essentially design materials or problems (e.g., "How might we design tools to make coordinated work go more smoothly?"), or as key political and policy issues (e.g., "What forms of coordinated political effort yield preferable policy outcomes?"). Both viewpoints affect my own understanding of my work, and are salient to the VCC's context as essentially an inter-governmental technology system. In synthesizing different treatments of these concepts, and in particular how they have been made to relate to each other across different works, I will arrive at my own working definitions,

which I will carry through to my analysis chapters.

Finally, I will touch on how "design" has been used outside of our typical "design" fields to describe the kinds of actions implicated in the VCC's longer-term project. This will foreshadow some of the commentary on design I will engage with in the Methods chapter, and strengthen the intuition put forth in the work infrastructure perspective concerning what "design" can be when the system being "designed" has so many political and organizational components.

2.2 Prior Publications Related to VCC

My research work on the VCC began with a focus on the work activities of some of its stakeholders. In 2021, my colleagues and I published a study of Seattle Department of Transportation Transportation Operations Center (TOC) operators that developed the idea of constructing shared situational awareness between different work settings [75]. It built on traditions of studying control rooms in CSCW, but also included work from ergonomics and human factors around the concept of "situational awareness," which allows accurate, detailed observation and analysis of real-time conditions in safety-critical work. The observations conducted for this paper happened shortly before other observations I conducted for the VCC project, and it began to shape my understanding of how incident information is created and shaped by different parties, and how that might be represented in a shared system like the VCC. I have carried that interest in the ways systems span organizational boundaries to support shared work into this dissertation.

In 2023, I led a paper in which the VCC fieldsite was compared to two other longer-term interorganizational information infrastructure development sites, one in technical education and one in scientific collaboration [76]. My coauthors and I brought our in-depth knowledge of each of three very different case studies to bear in proposing the concept of the *multiorganization*. This term, which we provisionally used to describe the kind of entity we had each engaged with in our cases, is an interorganizational collaboration whose distinct identity is developed in part through the development of an infrastructure system. That idea is further developed in this dissertation through my description of scaled stakeholders in a coordinative space, and refined with specific ways the development of the system interplays with the development of a coordinative space and its multitude of scaled stakeholders.

Most recently, I worked with colleagues who had participated on the VCC project extensively

to analyze the development of the VCC's Concept of Operations (a design policy document) as a kind of "epistemic object." This is a notion from science studies and design to understand how design ideas are iterated socially [77]. It explored some of the strategies used in and around the Concept of Operations development process to serve open-ended and ambiguous design explorations in the more controlled design environment of the VCC. Documenting and analyzing the rhetorical and imaginative activities the design team used in developing the VCC informed my approach to designers as stakeholders, and the discursive framing influenced my analytical approach to a broad set of design activities I examine in this dissertation.

In sum, each previous research work on the VCC provided some empirical and conceptual building blocks that I extensively expand upon in this dissertation.

2.3 Domain Background: Infrastructure and Intelligent Transportation Systems

Contemporary traffic incident and congestion management (TIM-CM), the problem space for which the VCC design project was developed, draws from and supports a wide suite of technologies collectively known as "Intelligent Transportation Systems" (ITS) [110]. As a part of transportation research and engineering, ITS spans the design, implementation, and monitoring of such systems as traffic flow sensors [1], ramp meters [2], vehicle-to-vehicle communication [163], and data standards [155], among many others. In the recent engineering literature connected to ITS [166, 53, 63], improved algorithmic sophistication, service delivery, and security and privacy are common areas of interest, along with the expansion of social media use for traffic communication [83]. Changes in the configurations of such technologies enable those who manage travel and roadways to shape how people travel and how safe that travel is. It also shapes what is analytically susceptible to improvement and further investment, via what kinds of data are recorded and what sorts of conditions are monitored.

The VCC can also be seen as falling under the category of "civic technology," which has a history of study in CSCW. These studies (e.g., [82, 104, 32, 44, 128]) typically focus more on improving connections between the public and government actors, such as the challenges of helping citizens more actively and agentically participate in governance via design processes or technology systems [14], or develop resilience [39, 128]. Others do study the government entities themselves, often in critical assessments of "smart cities" projects [161, 31, 101], or in equity-based examinations of

algorithmic governance practices [130].

Some CSCW research also examines technology use among government employees. For example, Rooksby and Sommerville [125] studied the range of social media use among employees of the UK Home Office, arguing that the use of such systems challenged the organizational and processual boundaries of government work, in both positive and negative ways. An early CSCW paper by Bowers [15] examined an ecosystem of hardware, software, and routines within which a pseudonymized unit of British government operated, though the study does not place strong emphasis on the unique characteristics of government offices as a type of workplace. In another early CSCW paper, Snellen and Wyatt *did* explicitly center the unique characteristics of public service work as a site of CSCW applications. They argued that "public administrations in modern democratic societies are in both their organizational structures and their activities subservient to legal and political norms in a way that is different from private organizations; therefore, public administration cannot slavishly emulate CSCW applications that have proven themselves in a private context" [143]. They further add, "Public administrations have to assess forms of CSCW in the light of the normative structure that is specific for them," which my work also supports from its own attempts to build and evaluate systems.

Further, CSCW has a rich history of examining the intensive work of control rooms [153, 65], particularly in its earlier days. I call attention to these works because many core VCC users work in control rooms in regional departments of transportation. These fine-grained, often ethnomethodologically [54] precise examinations of shared action and situational awareness [43, 75] have yielded rich insights about how people use technology together in demanding and fast-moving settings.

However, civic technology studies in CSCW don't usually focus as much on the "interface" between different geographically proximate public organizations with overlapping jurisdiction and responsibilities. This is where the VCC and the study of it lie. Other disciplines such as management and organization studies treat these areas more explicitly, however, and as such I have drawn significantly on them at later points in this literature review. I hope to open up the study of these kinds of design projects from a CSCW perspective. This configuration of actors, and the use of a design perspective on their activities, opens new opportunities for understanding a highly consequential genre of "computer-supported cooperative work," one whose successes, failures, and general peculiarities bubble up to shared social life in general.

Moreover, the VCC's operational sphere is unusual (or at least, unusual in the literature) in that it spans a wide range of intensity or severity levels. That is, the kind of traffic management work the VCC supports encompasses a range of work from major emergencies down to minor fender-benders or clearing bits of debris from the road. Most CSCW-related work studying government or public service operations focuses on emergency-specific operations (e.g., [121]) or on more daily routine processes [15]. Part of what made the VCC inherently challenging to create and make legible during the design phase was to understand the ideal range of traffic incident severity in which the VCC could be most useful; the "sweet spot" was something in between a minor fender-bender and a major regional catastrophe, but it was hard to definitively identify. An incident's severity can also change *during* an incident, which means it may require many different different configurations of shared work. How to operationalize these concerns is a serious design challenge and a specialized and particularly fraught example of the socio-technical gap [3] in CSCW.

2.4 Infrastructure

The notion of "infrastructure" has been central to many strands of work in CSCW, including my own. Leigh Star's [146] seminal framework allowed scholars to identify infrastructures according to analytical, sociotechnical characteristics (such as becoming "visible upon breakdown" and being "built on an installed base") rather than as already well-known types such as bridges and sewage systems. This meant that the increasingly important world of technical infrastructures and the human processes built around them could be opened up to CSCW study in new ways.

In CSCW and HCI, infrastructures are usually implicitly or explicitly characterized as "enabling" systems: they support a variety of other work and processes (e.g., [106, 33, 142, 21, 80, 141, 40]). Whether by design or inertia (or, more typically, both), they persist across time scales, and thus by studying them we can begin to observe technology use and appropriation with a more historical posture than is often possible with other HCI research approaches [144, 78]. They can also be seen as sites where larger-scale concerns–such as governmental regulations–interplay with the kind of craft local practice that CSCW often studies via both regulatory constraints and resources for creating new practices and artifacts [93]. As infrastructure spans space and time, its enabling quality is significantly supported by the stability it creates. Edwards [41] even claims that "infrastructures simultaneously shape and are shaped by — in other words, co-construct —

the condition of modernity. By linking macro, meso, and micro scales of time, space, and social organization, they form the stable foundation of modern social worlds." Infrastructure is both a concept and practice, which both bridges different scales (force, time, social organization) and offers a way of 'comprehending their relations'.

Processes and data that *traverse* organizational boundaries–part of the concern of this dissertation–require additional work and attention, since the tacit knowledge that supports their use intra-organizationally can be lost when such boundaries are crossed. Supporting this requires understanding and perhaps even intervening in the human infrastructures [91] of pre-existing operational relationships between agencies. Human infrastructure refers to "the arrangements of organizations and actors that must be brought into alignment in order for work to be accomplished." Again, bringing the lens of infrastructure to these kinds of human activities helps scholars see the meaning and function of the activities differently, and thus the sociotechnical system they are a part of differently. Reliance on human infrastructure is not, for example, always to be seen as a flaw, but as a normal part of infrastructure operation.

Infrastructure being used in such a flexible, generative way has also invited some critiques. Larkin points out that since infrastructural aspirations are so tied into political goals, it need not always be "invisible" in use and in fact can be an explicit expression of how a good shared life might be lived [87]–using similarly lofty language to Edwards [41] but in a more pointed fashion. The popularity of the term also makes it harder to use precisely and consistently, as observed by Lee and Schmidt [93]. In essence, the term "infrastructure" has become "infrastructural" itself, and may be more load-bearing than it was initially intended to be. I will use the general term "infrastructure" in a fairly broad sense, to indicate an enabling system, whether digital, physical, or processual, that is meant to have a relatively long lifespan and to support other kinds of work, including new kinds of work not yet specified when the system is created.

In this literature review, my focus will be on one slightly more specific type of infrastructure (work infrastructure), but since the domain of the VCC project involves the use, analysis, and maintenance of so many other kinds of infrastructure, the general conversation and the conceptual territory of this term remain perpetually relevant.

2.4.1 Work Infrastructures

The VCC's users make use of a wide variety of information systems in their traffic and incident management responsibilities, many of which can be called *work infrastructures* [117]. These work infrastructures shape both intra- and inter-organizational practice, as well as information sharing and the use of tacit knowledge [118].

Per Pipek and Wulf, work infrastructure is "the entirety of devices, tools, technologies, standards, conventions, and protocols on which the individual worker or the collective rely to carry out the tasks and achieve the goals assigned to them." Their "unique versatility" allows them to be used for many purposes, which is invaluable in complex work environments. Existing work infrastructures both feed into the VCC (through, for example, computer-aided dispatch feeds being imported into the VCC) and shape how users interpret and give their finite attention to the VCC. They may also, over time, compete with the VCC or fuse with it into new heterogeneous forms of work infrastructure.

The complex environments of work infrastructure makes analyzing or designing to them difficult. One method Pipek and Wulf identify for managing this complexity is a "layered approach and standardization":

> To manage the complexity, a number of technology layers emerge (for example, local area networks, organizational intranets, national network infrastructures, the global Internet). These layers may be far removed from the worker's computer as an infrastructure outlet, yet may still have various immediate effects on the worker's choices to proceed with her work. The layers interoperate by abiding to standards; while some standards (and transitions to new standards) remain in the background of the work environment (for example, moving from IPv4 to IPv6), others emerge in the user's foreground (for example, standards needed to synchronize data between contact databases on a desktop computer and a mobile phone).

This dissertation will explore some ways the often non-linear and heterogeneous processes of work infrastructure evolution resist both clear and consistent "layers" and (to a lesser extent) standards. But the idea that organizational and technological complexity, as an ongoing problem to be managed, can help to explain organizational and technical structures, is valuable.

A hallmark of work infrastructure is that it is "reflexive," and can be developed and improved *within* the infrastructure itself. The "point of infrastructure," or a sort of moment of crisis in an infrastructure's use, is essentially a recognition among the work infrastructure's users that something is broken, suboptimal, or otherwise in need of rethinking. These crises can be positive opportunities to seek improvements in the structure or processes of the infrastructure, and focusing on them is a key part of Pipek and Wulf's attempt to deconstruct the distinctions between "users" and "designers," and further between "design" and "use."

Later work by Vestues, et al. frame this recursive ability of a system-in-use to be improved within itself as "platformization," whereby "platforms as digital artifacts evolve in a recursive manner; the platform itself is used as a resource for evolving the platform further" [158]. Platformization is characterized by "separate but related processes of "de-coupling" and "recoupling". In the decoupling process, legacy systems are dismantled into modular applications, while recoupling processes entail a restructuring of the software development organization. Notably, the goal of "dismantling" existing applications rather than finding ways to coexist with them or strengthen them separates them from a more infrastructural perspective.

A similar concept to platformization is that of Large Technical Systems, or LTS. Edwards contrasts infrastructure with the similar notion of LTS, as elucidated by Hughes [70]. The development path of LTSs tends to start when "an unorganized, diffuse set of inventors and tinkerers create new technological possibilities." Eventually, sociotechnical visionaries develop a set of capabilities around a key system function, such as the transatlantic Morse code system, which included communication protocols, policy, and physical equipment. After a time, standardization around a particular implementation emerges and the system obtains inertia–its own "installed base." Edwards observes many similarities with the histories of infrastructure, with the key difference that LTSs are built around a "technological core" (though they can involve non-technological artifacts like legislation, and social entities like organizations) [70].

In the case of both platforms and LTS, the emphasis is more (though not entirely) on the technology system's functions and capabilities. The purpose of the work infrastructure framing, while it can often point to similar or even the same systems, is more upon the style of use, the locus of change and improvement, and the connection to work practice.

Pipek and Wulf's coupling of infrastructure theory concepts with clear and direct design guide-

lines is a great strength of their work infrastructure framing. To be clear, I am taking the perspective that the VCC may come to act as work infrastructure in some ways to some types of users, but it is not a given, particularly since use of the VCC is far less formally prescribed for most users than their other systems are. How much the very different types of users "rely" on the VCC to carry out the tasks "assigned to" them can vary significantly. The VCC is instantiated as work infrastructure very heterogeneously across the different agencies and operational subcommunities, since the agencies still have different internal systems, regulations, and work practices. Here, where there are occasional and partial overlaps between internal and inter-organizational systems, "infrastructurality" (how systems flexibly yet reliably support a wide variety of work) is foregrounded continually by necessity. It may not be able to fade into the background like many other kinds of infrastructure can. In short, "work infrastructure" will be a key analytical lens to understand sociotechnical dynamics in the places where the VCC is introduced. However, the way work infrastructure is often understood, based on organizational requirements and the resources people use to meet those requirements, is also somewhat limited in an inter-organizational work context, so this work will examine and refine the notion of work infrastructure in that light.

Pipek and Wulf's work casts a long shadow, taken up by both Information Systems and CSCW research. As Lanamäki and Väyrynen observe [85], there are some general disciplinary differences between CSCW and IS, though of course there is significant overlap. In very broad strokes, IS research has more of a "theory fetish" [85] while CSCW tends to be more effective at observing real examples in practice. Though both IS and CSCW can build conceptual and causal models of actual information systems, this is more common in IS [111, 24, 12]. Both fields use qualitative and quantitative data, but IS has a stronger positivist bent and has a greater focus on systematizing findings, such as with surveys [24]. System-building itself is common in both, and can be used to "prove out" the theoretical concepts being developed (such as [111], compared to, for example, our own work in the VCC). While CSCW tends to focus more on the end user, IS has had more of a focus on organization-level dynamics. Sociotechnically, CSCW tends to treat technology as the 'problem' which creative people strive to fit into their practices (and thus is typically somewhat more power aware), whereas in IS there is a stronger emphasis on bringing practices into compliance with technology. This dissertation will borrow freely from both disciplines, but will tend to use more of a CSCW perspective on interpreting findings and applying theories.

2.4.2 Integrating Embedded Infrastructures

My research question requires understanding the dynamics of creating and integrating infrastructures into existing sociotechnical systems across different work/operational contexts. Embeddedness is a key component of Star's classic description of infrastructure. To recapitulate Star's original phrasing, the quality of embeddedness has to do with the fact that "Infrastructure is sunk into and inside other structures, social arrangements, and technologies. People do not necessarily distinguish the several coordinated aspects of infrastructure" [146]. That is, the ways infrastructures get "sunk into" other structures can make the infrastructures harder to inspect directly and discretely. Even those directly operating infrastructures–interacting with them as structures–do not necessarily perceive all of their meaningfully different components or associated parts when operating them. They can, much of the time, be operated as a "gloss" of otherwise complex articulated structures, or as a gestalt. This is certainly the case for work infrastructures, which can connect to dozens or hundreds of other systems (internal or even external, via APIs or standard practices), and thus which many workers need never fully perceive. Yet even what they do not perceive affects them, especially when systems or subsystems stop working as usual.

While embeddedness has become an important concept in infrastructure studies, most work that makes use of it does not fully elaborate on what it consists of and the processes by which it arises. One notable exception to this is from Fürstenau, et al. (2019), who employ a multi-method case study of a recycling firm to identify processes by which "individual systems become embedded into digital infrastructures," and in so doing to build a dynamic model of embeddedness [51]. They explicitly focus on the more gradual, nuanced, internally-focused processes of embedding rather than on major, dramatic, or externally-imposed inflection points. *Parallel processes* involve systems becoming embedded independently of each other; *competitive processes* happen when the embeddedness of one system grows "at the expense" of another; and *spanning processes* create bridges between different embedded systems. Their conception of embeddedness is a networked one where individual systems evolve interdependently with others in the infrastructure.

Each process can create different forms of *inertia*, where a given configuration or system becomes harder to "resist" or change. Parallel processes can lead to a system that "becomes a "honeypot," attracting new systems and potentially shadow IT systems" [51]. The competitive process "reflects

inertia in a kind of seesaw arrangement, whereby the gradual decrease in the embeddedness of one system translates to the in-creasing embeddedness and subsequent inertia capacity of another" [51]. Finally, spanning processes can create inertia beyond the pure *number* of connections when they connect multiple "heavy" systems. So, the number of connections is important for inertia, but so is the importance of a given connection. Inertia can be positive or negative, but is framed in the paper in a slightly more negative fashion, as it can inhibit innovation, or cause a misalignment between actual system effectiveness and usability.

The processes by which such integration can happen can also be understood as the creation, exploitation, and supercession of "scaffolds." As Griesemer and Shavit [62] explain, these scaffolds support functional development by lowering "fitness barriers" to developmental activities or achievements; which then make new competencies available that become the "self-scaffolding" for later development. If this language sounds biological, that is because it is inspired by findings in biology and ecology, but is also extended to social systems (which could include sociotechnical systems). As part of these developmental processes of scaffolding, "generative entrenchment" occurs when "the dependencies created by increasing use of the new competencies make them essential, stabilize many of their features, and engender further elaboration of scaffolding on top of them." Scaffolding in this piece is generally described more positively, and as sometimes a transitional phase rather than something permanently "weight-bearing," though the expectation is that as the system survives new scaffolding is created and "generative entrenchment" occurs. As time passes, more functions are enabled and new connections can be made.

The VCC is a potential stimulus to or degrading force on the embeddedness of existing work infrastructures. It offers a vantage point on information and practices relevant to each work group and agency, but external to it. Over time, how does it scaffold, span, act in parallel to, or compete with existing systems? Do parts of its functionality fall away from active use as the learning they are supporting are accomplished? The VCC is a collection of system functions held constant across several organizational, political, and technological environments, *as well as* an evolving shared environment.

2.4.3 Challenges of Incorporating New Infrastructures

In the messy world of inter-organizational shared work, there is conflict, overlap or redundancy, and dysfunction. To discover and implement a system complex enough to answer the challenges of inter-organizational shared work, such things are to be expected, and examining them offers fruitful ground for deepening understanding. One work that provides some insight here is Jabbar and Bjørn's [74] concept of "infrastructural grind," examined through a study of Blockchain technology being introduced into the shipping domain. This concept describes one way that infrastructures can integrate with each other, and is "the processes by which two information infrastructures grind against each other, and potentially how new technological infrastructures succeeds in penetrating the new domain." This mutual "grinding" can allow the new technology to be embedded into the installed base over time, but under certain circumstances, can also allow domain-specific concepts to be promulgated upward into the new technology. Yet as Edwards [41] notes, speaking of technological change, "the solutions adopted are not necessarily the 'best' ones, if such a term is even coherent; they are simply those which endure in the market. The principles of technological change are frequently not 'survival of the fittest,' but rather 'survival of the surviving.'" So the grinding that may take place may be a selective process whereby optimizations (or at least improvements) arise, but that is not necessarily true–to observe what has happened post "grinding" does not mean to observe the ideal solution of a problem.

In the case explored by Jabbar and Bjørn, a new *information infrastructure* was introduced and "grinded" against another. However, especially in complex multi-organizational and multi-jurisdictional systems, different modes of infrastructure (physical and informational) can also interact. Hennigsson and Henriksen describe one such case of "double infrastructure" where an information infrastructure (an eCustoms system) partly replaced a previous paper-based system and lay alongside the physical infrastructure of international customs originating in Denmark [66]. The eCustoms system is built on an "installed base" of many core web technologies like XML and FTP, different from the "installed base" of the complex paper-based system it was replacing; essentially, it has its own history and trajectory of infrastructural development. A potential implication of this case is that an innovation different in modality from a prior system may potentially rely on a different installed base–even if its functional purpose is the same.

2.4.4 Synthesis of Infrastructure Concepts

In these sections, I have reviewed different concepts relating to infrastructure: how it has been applied in CSCW scholarship, and what the creation, adjustment, and entrenchment of "work infrastructures" can reveal about the dynamics of evolving inter-organizational sociotechnical systems. I have described some similar notions, such as LTS and platforms, both to show the general direction of scholarship around these important systems, and to tease out some differences between them (different models of how they change, whether they have a single technological core or not, etc.). The system focus of these concepts is important for their intellectual commitments, but for my purposes, must be supplemented with some more explicitly social and organizational works.

2.5 Coordination and Interdependence

The Research Question is specifically concerned with understanding how interdependent stakeholders innovate their shared work. This "shared work" can be delineated in a number of different ways. Therefore, it will be critical to carefully treat the notions of "coordination" (and related concepts of "cooperation" and "collaboration") and "interdependence." I will survey some particularly helpful approaches to defining and operationalizing the key notions of "coordination" and "interdependence." These approaches come from a range of academic fields, including some outside of CSCW and HCI. In many of these fields, coordination and interdependence are connected, sometimes to the extent of using one to explain the other. Following this analysis, I will present my own working definitions of these two terms which will be used for analyzing my data.

2.5.1 Models of Coordination, Cooperation, and Collaboration

The VCC's operational stakeholders are continually coordinating their work in the dynamic, data-intensive, safety-sensitive, jurisdiction-spanning work of traffic incident and congestion management. The VCC is introducing a new tool for coordination and collaboration, with an explicit project goal of *improving* coordination and collaboration, particularly in the notoriously unpredictable, resource-draining realm of major traffic incidents. While CSCW is about studying cooperative work, in this case, shaping coordination/cooperation/collaboration is an explicit design goal, so it is worth exploring these concepts in some depth and breadth.

Three concepts of coordination that have been influential in CSCW are Schmidt and Simone's notion of "coordination mechanisms," Lee's Model of Coordinated Action, and Gerson's distinction between "articulation work" and "metawork."

Spurred by the need to understand how computer systems can help reduce the complexity of coordinative activities, Schmidt and Simone articulated and developed the notion of *coordination mechanisms* [134]. Cooperative work, in their framework, is constituted by "the interdependence of multiple actors who, in their individual activities, in changing the state of their individual field of work, also change the state of the field of work of others and who thus interact through changing the state of a common field of work." Further, because it involves multiple actors, cooperative work is "inherently distributed," both in time/space and in the sense that each actor is at least somewhat autonomous in their specific activities. This tension between autonomy and interdependence can create "confusion and disorder," and thus activities must be "coordinated, scheduled, aligned, meshed, integrated, etc. — in short: articulated" [134]. A coordination mechanism–which can be but not need be computerized–is made up of two "devices". One is a coordinative protocol, and the other is an artifact, "as a distinct and persistent symbolic construct, in which the protocol is imprinted and objectified." The artifact works to objectify and provide permanence to the protocol it is a proxy for. Similarly to boundary objects [147], it must convey relevant information, in this case the stipulations of the protocol, in a situation-independent manner.

Gerson [58] developed further Strauss's notion of "articulation work" into "local articulation" and "metawork." This was motivated by the observation that trends in uptake of networked technology allowed work to become both "hyper-distributed" and "hyper-accessible." Work became more interconnected, yet lost the kind of immediacy that allows easy awareness of what others we work with are doing. Gerson used "local articulation" to refer to Strauss's original sense of articulation work, "making sure all the various resources needed to accomplish something are in place and functioning where and when they're needed in the local situation. This means bringing together everything needed to accomplish a task at a particular time and place" [58]. The newer term "metwork" referred to "putting together tasks, task sequences, task clusters—even aligning larger units such as lines of work and subprojects—in the service of work flow." While there is overlap in the two terms, the greater abstraction implied in metawork can lend itself to creating policies and structures.

Drawing upon both of these models as well as others from CSCW, human factors, and sociology, Lee later developed the Model of Coordinated Action, or MoCA [92]. Coordination is modeled as the interdependence of two or more actors who, in their individual activities, are working towards a particular goal through one or more overlapping fields of action. Their coordinated action can be characterized along seven dimensions: synchronicity (asynchronous to synchronous); physical distribution(same or different locations); number of communities of practice (0 or more); nascence (already routine or in various stages of development); planned permanence (shorter or longer term); and turnover (from low to high). This model can accommodate different types of coordinated actions, from individuals working dyadically on a single task, to multiple complex organizations undertaking multi-year programs. Participants are either acting within a single common field of work or within multiple overlapping fields of work. Their goals can be different as long as they are compatible with the same overall trajectory.

Task Dependencies, Ordering, and Shared and Conflictual Purpose

Coordination has, at a minimum, to do with completing tasks that have some connection to tasks other entities are doing. Malone and Crowston, for example, frame coordination as "managing dependencies among activities" [98]. These dependencies can exist within histories of social relationships–as I will discuss more in depth when I describe the work of Chisholm on regional transportation networks–or between systems or tasks (such as an order form needing approvals from a party not directly carrying out the order) [132]. Meanwhile, Griesemer and Shavit [62] describe coordination as literal "co-ordination," ordering activities in space and/or time. There need not be any deliberate interaction between the parties. For them coordination can, under the right operational and social circumstances, develop into "cooperation" (where entities do intentionally work together but potentially not for a shared purpose), then potentially into "collaboration," where shared purpose is key and a sense of group identity and delineations of shared work are established and reproduced over time. Some of the differences in these definitions come down to differences in focus. Malone and Crowston, as an example of studying coordination as a purely human endeavor, already place the term "coordination" at the level of deliberate shared activity; whereas Griesemer and Shavit, who approach it at a lower and more general level that can include

ecological processes, do not.

Like Chisholm whose work I discuss below, Malone and Crowston observe that some amount of goal conflict is usually always present during coordination; and that this is not necessarily a bad thing, especially at the macro level of the entire system, where dialogue and competition can produce greater innovation. The Griesemer and Shavit view does not necessarily portray goal conflict as generative. At times conflict may simply be something to be "coordinated around" (such as when trying to share the road with other drivers). At higher levels of cooperation/collaboration, conflict may be "destructive" for the collaboration entity but represent a positive outcome for component entities, "e.g. when a cliquish group shuns interaction with other such groups and in the process impedes everyone's progress. These cases can be understood as recursive problem solving strategies running in the opposite direction of our idealized sequence" [62].

As Malone and Crowston observe, there may always be details that we (the observing researchers, or even designers attempting to create interventions) miss and that have an outsize impact on coordinative tasks, such as subtle layout or interface elements [98]. The additional impact of dependencies between participating entities may compound this issue further. Thus, it is hard to tell what small nuances will eventually have a large and even explanatory impact on the sociotechnical system as a whole. System design, policy-craft, and social integration simultaneously and interdependently influence coordination.

One example of a close study of interfaces and task coordination is Pine and Mazmanian's ethnographic study of the implementation of an EHR (electronic health record) system at a hospital obstetric unit [115]. Pine and Mazmanian found that the EHR turned a previously "productive disconnect" between the workplace's formal logics and its actual situated practice into an "unproductive disconnect." They identified what they call a change from "artful coordinating" (where formal logics, context, and "situated contingencies" were resources to effective action) to "contorted coordinating" ("characterized by working around formal logics of the EHR while struggling to meet the demands of local context and situated contingencies, thus undermining predictability.)" Formal logics always vary in some ways from situated practice; however, formal delineations are necessarily built into work process systems that are used. Therefore, those formal logics still shape expectations of how work unfolds. Pine and Mazmanian ask what happens to ongoing coordination when formal logics are imposed on situated practice with an "assumption of perfect alignment."

In this study, nurses were often unwilling to contact doctors for corrections to orders, not wanting to burden or bother them even when they were the ones who caused the error. The inflexibility of the new system and the configurations of roles and permissions made it more difficult and time-consuming to avoid doing this. The insights of this work are rich, and show several important ways that coordination systems can be counterproductive when the work they support is especially complex. However, the extant organizational structure and its pathologies appear to be treated as a given, and success in system design/implementation means effectively coping with these pathologies. In the work of this dissertation, the organizational structures, relationships, and dynamics that can give rise to productive or contorted coordinating are still under development, and the system design is meant to be a part of that development, offering different analytical opportunities.

2.5.2 Inter-Organizational Collaboration

Coordination and shared work in the VCC must be understood, not only from the general intellectual underpinnings of coordination and infrastructures, but as an issue of coordination and collaboration *between* organizations, with all of the logistical, technological, and policy complexity that can entail. The VCC's work must happen largely in a complex "interface" [140] between public service organizations, each of which is also internally complex and has internal work infrastructure commitments that shape their employees' understandings of their responsibilities. Navigating this internal complexity with respect to shared inter-organizational process will be a key aspect of my analysis. However, inter-organizational system development has been less emphasized in CSCW publications. Notable exceptions include studies of cyberinfrastructure [148, 67, 91], which tend to focus on infrastructuring for larger research projects across academic institutions; this work has provided significant value in terms of models of coordination across different group sizes and types of work [**?**, 113], as briefly discussed above.

While no CSCW literature perfectly matches the working environment of the VCC, it would be useful to examine some relatively close matches. Recent work on "regional innovation centers" that help Small and Medium Enterprises (SMEs) diffuse digitalization innovations in rural Germany [84] helps to establish patterns of regional, inter-organizational technology and practice studies in CSCW. In particular, they observe how new artifacts and technologies (in one example, a machine

setup application for employees) can "spill over" between SMEs, requiring "the co-construction of new knowledge to appropriate artefacts to new contexts." Closer to the domain of the VCC, a study of computer emergency response teams (CERTs) in Germany [121] examines the impact of organizational structure and technology use in the effectiveness of collaborative cybersecurity teams. For example, those CERTs that are organized to interact more directly with government ministries, as opposed to with the IT operations providers themselves, can benefit from the government ministries' ability to coordinate more effectively between CERTs.

Chongthammakun and Jackson argue that "virtual organizations" in government can be an unexpectedly significant source of organizational change (and problems) in government [26]. Virtual organizations exist in several different spheres, and bear some resemblances to the "collaboratories" [50] described in cyberinfrastructure research, for example. Virtual organizations bring together functional aspects or workflows from multiple extant organizations, and are distributed across space and time, and computationally enabled and enhanced. In government, this can look like creating inter-agency "wraparound services" or "portals" for citizens. Yet as the authors note, the creation and management of such virtual organizations doesn't allow the configurations of work and responsibility even within contributing organizations to remain static. The virtual organizations aren't merely a "just-in-time" fusion of unchanged sources, but a potential source of change themselves. Establishing them often "requires forms of intra- and inter-organizational coordination that go beyond traditional boundaries, and may go to the core of organizational function, requiring government units to adapt their internal business processes, incentive structures, and roles vis-à-vis outside collaborators" [26]. What can appear to be a simple fusion of extant sources can bely tremendous complexity, and this disconnect may, as the authors argue, partly explain the high failure rate of business process reengineering in government.

Levels of urgency and escalation in collaborative work affect the structure and use of shared systems. Ley, et al. conducted an empirical study of decision-making practices around significant power outages in Germany, focusing on information exchange between participating organizations (fire departments, police, public administration, and electricity infrastructure operators, as well as general citizens) [96]. They derive design requirements for an "inter-organizational situation assessment client." Because this form of public service inter-organizational collaborative work centered on emergencies rather than on routine daily work, they claim that

> "it does not make sense to support inter-organizational work in situation assessment with IT concepts that require centralized, aligned procedures dominating the practices of the individual organizations. It is more appropriate to offer a **complementary infrastructure** that allows maintaining informal information sources and manages informal collaboration opportunities (particularly for the sensemaking and interpretation work for situation assessment) that can as well be individualized/localized" [emphasis added].

They claim that information access according to a "break-glass" model could help handle the challenging issues of disclosure and policy liability as important data crossed organizational boundaries. This study's concerns bear a striking resemblance to the conditions and concerns of the VCC project. Many of its suggested features–the ability to flexibly integrate external sources, the support of informal and nimble collaboration–were also at home in the VCC. Interestingly, as mentioned above, this design context did not have to contend with the range of intensity in work implicated in traffic incident management, where exactly when to "break the glass" is not so clear cut. It was also not studied as a long-term design project where design goals were explicitly intertwined with cooperation and community development goals. That means that stakeholders' goals for enriching shared knowledge and connection through system development were not as much of a focus. In this context, "break-glass" model it advocates appropriately balances the organizational and legal complexities of creating a collaborative system with the benefit it can provide. In the VCC's context, similar general design principles might prevail, but the model of delivery and management (that of seeking to incorporate the system into more regular work infrastructure) is different. Additionally, the VCC is partly complementary to agencies' existing systems, but its relative complementarity is a moving target as its adoption grows over time, the idea of which this piece did not address, but which infrastructurally oriented CSCW studies are driven to.

These helpful examples notwithstanding, this general domain of work is still relatively limited, not always entirely applicable to the particular context of the VCC, and rarely combined with deliberate design interventions. Therefore, I will draw substantively from works in organizational studies and management science, with a goal of increasing CSCW's own knowledge base in this domain.

Coordination Across Organizational Boundaries and Interdependence

To better understand how coordination across the boundaries of interdependent organizations works, I will significantly draw on an important work in organizational studies, Chisholm's study of formal and informal coordination among San Francisco Bay Area transit agencies in the 1990s [25]. It brings up operational concerns that stakeholder groups worked over time to grapple with and coordinate around, which in the hands of an STS or CSCW scholar would have more directly translated into system design investigations.

Chisholm's work is most known for its defense of informal coordination even in the relatively formal, cautious world of public transit. Informal coordination structures aren't to be seen as pathologies, but as a portfolio of often uniquely useful tools to solve or ameliorate inter-organizational coordination problems. According to Chisholm, informal structures are the "conduits through which bargaining and negotiation take place, while informal norms provide foundations for coordination activities, and informal bargains and agreements are frequently their products" [25]. Incompatible technology systems between organizations are one form of boundary that people seeking to coordinate have to contend with.

In particular, Chisholm claims that the informalities he observed "develop because individual actors in the system seek ways to reduce uncertainty resulting from inter-organizational interdependence. Uncertainty is produced because organizations, as open systems, depend on each other, but cannot control the behavior of others that affects them." A key insight here is that uncertainty is not only a general aspect of trying to take actions in the world, but a byproduct of inter-organizational shared action; and that informal adaptations to shared action help to manage that byproduct. We might see this as an organizational analogue of the "reflexive" aspect of work infrastructures, or of platforms.

Other models of the "three Cs" (coordination, cooperation, and collaboration) come from related fields where entities exhibit intentional shared action. For example, in public administration, McNamara [102] borrows from Thatcher's [152] model from health education, adapts it to (and operationalizes it in) inter-organizational studies to characterize different coordinative forms.

Like Griesemer and Shavit, McNamara's model arranges these "three Cs" along a scale of intensity of interaction. Unlike them, however, McNamara places cooperation (rather than coordination)

on the least interactive end of the scale. In her framework, cooperation is "an interaction between participants with capabilities to accomplish organizational goals but chose to work together, within existing structures and policies, to serve individual interests" [102] That is, the participants chose to interact, but have the option of acting independently. Meanwhile, coordination is in the middle, and is defined as "an interaction between participants in which formal linkages are mobilized because some assistance from others is needed to achieve organizational goals." Finally, collaboration is "an interaction between participants who work together to pursue complex goals based on shared interests and a collective responsibility for interconnected tasks which cannot be accomplished individually." Collaboration differs from cooperation and coordination in that it "require[s] much closer relationships, connections, and resources and even a blurring of the boundaries between organizations." She further claims that different conditions seem to facilitate different interaction structures in inter-organizational settings. For example, cooperative interactions may be more likely to develop "when operating procedures remain independent, implementation of partnerships is based on connections made by personnel at the lowest levels of the organization, basic information is shared through informal channels, and decisions are made by personnel independently" [102].

In sum, the intensity of interaction McNamara creates is one of decreasing autonomy (where in some cases, even intra-organizational policies and processes can change to support the inter-organizational agreement) and increasing interdependence. One important takeaway from this work, as we consider how coordination and interdependence are considered, is that even what counts as "intensity" of interaction isn't universal across disciplines.

There are ten dimensions McNamara uses to analyze different types of coordinative situations. They include, for example, "formality of the agreement" [between participating agencies], information-sharing, and how "turf issues" are resolved. Each is used to tease out differences between cooperative, coordinative, and collaborative arrangements. For example, regarding "formality of the agreement," cooperative relationships are based more upon the desire, rather than the requirement, to work together, whereas coordination relationships are characterized by more formalized relationships, allowing clear role definitions. In collaborative interactions, both formal and informal agreements are used; informal agreements can support the "evolutionary nature" of a collaboration, and can more readily change as the arrangement changes, partners enter or leave it, or even if the problem domain itself changes. This volitional aspect of formality of agreements tends

to be less emphasized in CSCW research; in organization studies and political science, political will appears to be more continually salient, though that does not always extend to the will or agency of lower-power end users!

Each of the remaining dimensions is used to further flesh out these analytical differences, but will not be described here. Rather, I will observe that McNamara's framework is particularly useful because it very directly and specifically treats inter-organizational coordination, with respect to dynamics of interdependence. It also allows some level of theorization about empirical conditions that lead to different types of coordinative arrangements between organizations. In the next section I will continue with specifically modeling interdependence of different kinds. I will continue to examine coordination because of the strong connection between the two concepts, but the emphasis will be more on interdependence specifically.

2.5.3 Models of Interdependence from Several Related Fields

The need for informal or formal structures to assist coordination is deeply connected to *interdependence*. In fields outside of CSCW, but related more generally to organizational management and improvement, many scholars have offered frameworks for understanding and analyzing interdependence–of what it consists, what drives it, and what can make it helpful or harmful under different circumstances. I will present and compare several of these models, then synthesize their components into one that I find most appropriate for my own work. These different disciplinary perspectives may be helpful for CSCW and infrastructure scholars who want to design for interdependent work settings.

Process, Social, and Policy Interdependence

Interdependence can come in many forms, and which forms receive greater emphasis in a scholar's analysis is often related, unsurprisingly, to their discipline's primary concerns or areas of interest. In this section I'll focus on inter-organizational interdependence, particularly in the public sector. It will take into account social, policy, and work process aspects of interdependence. I will begin by elaborating some of Chisholm's ideas on interdependence. I will then discuss how systems themselves can be interdependent.

Chisholm describes three types of interdependence: natural, artificial, and voluntary. Natural interdependence occurs when "a variety of forces beyond the control of the organizations immediately involved come together to cause them to become connected" [25]. An example he raises is a pattern where a significant number of transit patrons choose to take multi-agency trips. "Artificial" interdependence, meanwhile, occurs when a party makes deliberate effort "to link two or more organizations for some purposes of its own (which may have little to do with the goals or interests of those two organizations)." Finally, "voluntary" interdependence arises when organizations voluntarily enter arrangements to obtain mutual benefits. However, voluntary interdependence can sometimes become institutionalized and entrenched over time. Interdependence can arise at various levels of operational complexity. "Localizing" interdependence to the lowest/simplest level reasonably possible, according to Chisholm, improves the likelihood of finding an acceptable solution to a coordination or shared work problem, because this treatment of a coordination challenge lessens cognitive complexity.

Zafonte and Sabatier [165], in the domain of theoretical political science, borrow some of Chisholm's thinking on interdependence to better understand the dynamics of public organizations. They build on the "advocacy coalition framework" [127], developed originally by Sabatier and Jenkins-Smith to model specifically elite–i.e., decision-maker–behavior in complex policy subsystems. A policy subsystem consists of "those actors from a variety of public and private organizations who are actively concerned with a policy problem or issue such as air pollution control, mental health, or surface transportation" [127], not a technology system. The framework groups them into advocacy coalitions, which are all composed of actors from different institutions who share "a set of normative values and perceived causal relationships and who show a non-trivial degree of coordinated activity over time" [165]. Note the emphasis on *perceived* causal relationships rather than objective causal relationships.

The paper collapses multiple types of interdependence identified by Chisholm into "imposed interdependence"–essentially, imposed interdependence consists of all of Chisholm's varieties except for "voluntary interdependence." In this paper, they add the notion of functional interdependence as another possible driver of coordination. Functional interdependence means that either entities' actions are causally linked–think a state department of transportation changing speed limits on a highway, which affects the way the state patrol enforces speeding, and vice versa–or some external

actor has linked their actions for its own purposes. One very general assumption that underlies design projects is that stakeholders are choosing what kinds of tools they use, and how, for their own utility. If their activities are materially affected externally by imposed interdependence, this has an impact on the potential solution space for the design project. This is one area where the often narrower, system-focused empirical perspective of CSCW could learn from organizational and political studies, which seek to understand the exercise of agency in all its forms and at all levels.

Zafonte and Sabatier then ask whether functional interdependence affects the influence of shared beliefs on coordinated action, and, what type of shared beliefs "provide the principal 'glue' of coordination." The Advocacy Coalition Framework as originally laid out claims that policy core beliefs are most central [127]. Zafonte and Sabatier found, however, that belief conflicts that are long term and affect many people may have larger consequences for coordination than even more "core" policy issues that are less obviously and frequently salient. Interdependencies are not always additive when it comes to coordination; imposed interdependencies can force more interaction between conflicting organizations, which can reduce cooperative behavior. So in this case, overlapping function makes for more conflict and worse coordination. I will develop this idea in later chapters in terms of "negative coordination."

Zafonte and Sabatier's proposed definition of coordination is "the spectrum of activity in which one party alters its own political strategies to accommodate the activity of others in pursuit of similar goals." They further distinguish between "strong" and "weak" coordination. Strong coordination would meet strict criteria like the development of a common plan of action, communication of it to all relevant parties, and acceptance and implementation of the plan. "Weak" coordination occurs when actors monitor each other's political behavior, "and then alter their actions to make the political strategies complementary with respect to a common goal." They explain that weak coordination is useful in that it provides mechanisms for actors to develop complementary strategies without paying the full costs of implementing unified plans, and can help track political cohesion over longer time scales.

Yet because of the focus on elite beliefs, this leaves open the question of *whose* beliefs are operative and how. The work does not fully address this. "Elites" at the top of decision-making have functional concerns that are based more on larger goals and aspirations, because their scope of concern is more general and strategic. The lower-level workers have more granular tasks and

less predictable and general beliefs about policy and implementation. So, in summary, this work is exceptionally helpful in identifying a government-specific relationship between interdependence and coordination. But it is still very top down, treating organizations as more internally simple than they are.

Elston, et al. [42], citing Tjosvold [154], point out that interdependence can be "socially constructed." That is, while there many be a number of elements that connect the operations of different entities, the salience or importance of each element is not a given. Note the similarity to the Advocacy Coalition Framework's portrayal of "perceived" causal relationships as described above [165]. Different actors can emphasize (rhetorically) or build upon the salience of an aspect of interdependence.

This framing creates a sort of causal relationship between (imposed) interdependence and the "right" level of collaboration. I should note again that in this work, identifying the "right" level of collaboration presupposes this "cost" model of interdependence and coordination, which is less common (or at least less explicit) in discussions of collaboration in CSCW. That is, in more politically oriented work like this, Chisholm's, and Zafonte and Sabatier's, coordination and interdependence impose cost in terms of expense, time, or operational complexity on the actors that must be justified and, in many practical cases, is not. Elston, et al.'s survey work in this paper analyzes preferable levels of collaboration by using a kind of "tipping point" approach where "diseconomies of scale" eventually emerge.

System Interdependence

Less of a focus for scholars in administration or organization studies, but no less relevant to understanding the development and use of the VCC, is how technology *systems* can operate interdependently. These interdependencies can be formal and prescribed, a hidden "shadow system" where people secretly mirror data from one system to another, or anything in between. The ethnographic aspects of my work on the VCC require me to place equal emphasis on more and less formal system interdependencies, and how their users think about those interdependencies.

Before explicitly discussing system interdependence, it would be useful to mention the work of Bates, et al. on conceptualizing "data journeys" [11]. The reason I highlight this concept is that

when systems are interdependent with each other, their interdependencies can often be modeled through watching data pass through different system components, undergo transformations, and be molded and shaped by the needs of different systems and organizations on the way through. A "data journey" is the passage of a "data-object" (in the case of their original paper, a temperature datum in climate science) "through interconnected data infrastructures, from its original 'raw' state, to being cleaned and otherwise processed, to becoming an input into various forms of derived data." Later, Leonelli and Tempini described data journeys in a more "verb-ified" way: "designating the movement of data from their production site to many other sites in which they are processed, mobilised and re-purposed. 'Sites' in this definition do not need to refer to geographical locations, though this is often the case: they also encompass temporal locations and diverse viewpoints" [95]. Some of my early work on the VCC involved tracing computer-aided dispatch (CAD) data from its creation to its deployment and analysis. Through observing this process, it became clear to me that interdependencies can be shaped and deepened by the "erosion" or "deposition" of data as they follow their "journeys" in different systems.

de Bruijn and Herder [37] model their idea of system interdependence on the ability to analytically decompose large-scale systems into their smaller *subsystems*, which can be interdependent in multiple ways. Importantly, this structure of interdependence doesn't preclude conflicts, mirroring the socially and organizationally oriented findings of other scholars like Chisholm [25]. Optimizing the performance in one subsystem can result in worse performance in another.

This work outlines several dimensions of subsystem interdependence; by virtue of considering subsystems in terms of information flows, and inputs and outputs, their typology can be both detailed and clear. For example, the first dimension is "simple-multiple," where "subsystems can be interdependent by virtue of just one variable, e.g., 'information,' or can be related to each other in several respects simultaneously, e.g., information, energy, and raw materials." The second and third dimensions–"no feedback-feedback" and "linear-nonlinear"–treat the manner and degrees of effects between systems. Linear-nonlinear relationships identify the degree to which the functioning of a system is the "sum of all its parts," or the functioning of its component subsystems. If it is, then the relationship is linear. If a system can't be readily modeled in this way, or component subsystems seem to have "disproportionate" reactions to changes in each other, then it is nonlinear. One example of this, at least in the shorter term, is the current volatile relationship between urban

heating and generative AI usage via the construction and operation of data centers [1].

As subsystems, systems, and systems-of-systems grow in complexity, they often show emergent behavior and harder-to-model recursion. The system's more "chaotic, emergent, and unpredictable" nature can thereby render the "simple" concept of recursiveness a more complicated one [37]. As a result, "a system of systems may display other or new behavior that is not a sum of subsystem behaviors."

As systems and subsystems interact over time, such unexpected behavior can emerge as practical problem-solving on the part of users. Andriani and Cattani [5] define "shadow options" as "functions of technological resources that were unknown when they were originally acquired or created." The employment of shadow options can happen via *exaptation*: "the situation in which a technology designed to perform function A is discovered to be preadapted to perform a different function B by serendipity or through search." Shadow options are portrayed as "options awaiting recognition"; and they represent the "generative engine" of real options [5]. Previous investments can create a "trajectory of unfolding strategy choices that is based on the interdependence between the resources a firm owns or controls and the strategic possibilities that it can achieve through them." In Star's terms, these "shadow options" can be seen as an emanation of infrastructural inertia and embeddedness, *even though* such unanticipated functions or affordances were not considered when the system was created and may be treated in a stigmatized way until they are legitimized by some process. System interdependence therefore needs a broad view to fully understand.

Work by Cabitza, et al. [19] treats in some detail how system elements support interdependence (including inter-organizational interdependence) in design. Interdependence in their formulation means that "local primary work units are increasingly specialized to improve their performance and effectiveness and, also for this reason, must be tightly interconnected to mutually exploit cooperative services, complement each other's capabilities, and provide each other with the necessary inputs and resources for their proper functioning." Interdependence here is connected to *specialization* and *division of labor*. This makes the demarcation of boundaries, and understanding how boundaries are crossed and why, critical. They introduce three new design concepts: seams, scars and sutures, based on principles of openness, underspecification, and interdependence, respectively. Seams and

[1] https://amenazaroboto.com/the-heat-behind-the-cloud

scars, which I will mention only in passing, have to do with the interaction of an IT artifact with a user at an interface level. "Seams" are affordances that indicate opportunities for a user to "tinker" with the interface or its functionalities (in contrast to "seamless" [20] design). Scars are affordances that indicate past interventions made by users: "in other words, scars indicate 'exploited' seams, made visible to let users know that something has been adapted locally, by someone, and can be adapted further" [19]. Sutures, which connect more directly to organizational aspects of IT, are the "interaction points" that connect disparate parts of a system/organizational boundary and allow them to exchange pertinent information. Sutures also allow a gradual "bottom-up" building of a new overall system. They help to extract data from their sources and present them to other systems "and therefore make handovers and inter-departmental (or even inter-organizational) work possible" [19]. Cabitza, et al. claim that sutures should be very *visible*, so users can track how boundaries were crossed and information exchanged, which can "enrich" the data set shared between different groups and promote collaborative awareness. However, they should not be easily *openable* by most users most of the time, particularly when there are data security implications with data crossing boundaries. The VCC was able to create certain "sutures" showing how data from different systems were integrated and report on their issues, but their visibility varied from user to user because each one required context and training to interpret.

Normative and Aspirational Interdependence

These different perspectives on interdependence target very different aspects of shared work, but many emphasize that simplifying work at the lowest level possible is desirable. What neither account covers is the *aspirational* interdependence found in the VCC project, which concerned innovation in both practice and system usage. This innovation was intended to increase, not decrease, the number of parties interacting with systems and information, and contributing their expertise to complex problems. This must be balanced with the appropriate and often legally regulated division of labor. Effective design work may help to resolve some of this tension, but as coordination changes over time, it is something that should be revisited and re-evaluated. Research in CSCW can be a useful tool to investigate and manage this tension through and around system-building, and observing the strategies users employ to navigate it.

2.5.4 Synthesizing Concepts of Coordination and Interdependence

Based upon these works in CSCW, public administration, systems engineering, and elsewhere, and in view of the particular considerations of my field site and project where system interconnection, complex shared work across a range of temporalities and urgencies, and inter-organizational boundary-crossing are all highly salient, I give the following working definitions:

Coordination: A collection of actions taken by two or more actors sharing a dynamic space, whether physical, virtual, or a combination of the two, to align other actions they are taking. It can occur in "real time" or asynchronously, as long as it is meaningfully time-bound. The aspect of temporal ordering–co-ordination–that often occurs in analysis across disciplines is also represented here, but I have tried to be precise about its characteristics, as I will develop in later chapters. I identify "cooperation" and "collaboration" as particular types of coordination. "Cooperation" at a minimum means meaningfully taking into account the needs and goals of the other actor(s), even if the primary actions being taken are mostly directed to an actor's own ends. Meanwhile, "collaboration" at a minimum means intentionally working toward shared outputs. In keeping with most of the works I've analyzed, I place "collaboration" as the most intensive of the three

Interdependence: A causal connection between the actions of two or more actors. Actors that are interdependent with each other may not have the same understanding of the interdependence, or value it in the same way. Indeed, actors may be unaware of their own interdependence with others. Actors need not be interdependent in order to coordinate. However, deliberate coordinative actions and, particularly, the intentional planning of coordination can change the nature of an interdependence, including reducing it (such as in the design of a process that reduces duplicative effort), increasing it, or changing its morphology (such as routing a connection from one department to another).

Neither interdependence nor coordination need be "positive" or "beneficial" to either party in order to be legitimate. However, trends in how entities coordinate or choose to shape their interdependence will likely track some level of "critical mass" of shared goals, even if understood differently by the different actors.

2.6 "Organizational Design"

Chisholm reminds us that coordination is more often a means to an end than an end in itself. An "organizational design," to him, is to be evaluated ultimately with respect to "the specific set of problems it is intended to solve, or the goals it is intended to achieve" [25]. Since the still-evolving community of VCC users/TIM-CM professionals in Seattle is emphasizing coordination *per se*, especially during its developmental period, this raises the importance of evaluating the VCC's second-order/teleological instrumental goals (e.g., traffic safety) through the lens of its goals of improving trust and coordination among its users.

This type of collaboration between organizations can potentially, under some circumstances, help build a new "organization" over time. Previous work [76] has raised the idea of a "multiorganization" that uses shared system development as part of creating and evolving a shared identity. This dissertation will extend that line of work by trying to identify how system design has been used by a wide range of stakeholders to support inter-organizational group identity, particularly in the context of parallel intra-organizational systems whose operation can create operational barriers between actors. The work of Weick and colleagues [160, 34] frames organizations as "sensemaking" bodies that must interpret and adapt to their environments, and has also been influential in CSCW (e.g., [7, 9, 136]), as CSCW scholars attempt to understand connections between organizational dynamics and system design. In this account, organizations *become* what they are in part through interpreting, understanding, and responding to the conditions of their environment, on a longer time scale, rather than only by the intense shared action of shorter-term sensemaking [160]. Because each participating VCC organization had a slightly different "environment" per Weick and colleagues, the addition of each new organization into the project also changed the multiorganizational environment, which then allowed the multiorganization to grow its nature over time.

In the political science sphere, "organizational design" can be compared to "jurisdictional design." That is, how might jurisdictional districts be understood and arranged to obtain positive political outcomes? Hooge and Marks [68] note that there are costs and benefits associated with any one approach to jurisdictional design, as there are with any kind of design decision. Dispersing governance across many jurisdictions offers more flexibility than concentrating it. Larger jurisdictions have value in that they can leverage economies of scale, and have pathology in that they can

impose one single rule across diverse regions/groups of people inappropriately. The authors suggest that economies of scale work better in more capital-intensive services/projects than labor-intensive ones.

Hooge and Marks describe two different types of governance that represent alternative responses to "fundamental problems of coordination." Type 1, or "general-purpose jurisdictions," have non-intersecting memberships (think adjacent counties or different mutually exclusive regions), operate jurisdictions at a specified number of levels, and exhibit a "systemwide architecture"; their basic structure is the same at multiple levels of their operation. They can benefit from economies of scale, collective bargaining, and "issue bundling" as needed. Type 2, or "task-specific jurisdictions," are created to solve specific policy problems such as setting up a technical standard or managing an urban resource. They can have intersecting memberships, no limit to their number of jurisdictional levels, and typically voluntary membership where people can belong to several at once. Type 2 jurisdictions are meant to respond flexibly to changing citizen preferences and functional requirements, since they address a particular topic. Because they have different purposes, both types are useful and valuable, but usually for different purposes.

The authors portray the "coordination dilemma" of multi-level governance as one of flexibility vs. the "transaction costs" of coordinating multiple jurisdictions. "To the extent that policies of one jurisdiction have spillovers (i.e., negative or positive externalities) for other jurisdictions, so coordination is necessary to avoid socially perverse outcomes" [68]. They formulate this as a "second-order" coordination problem because it involves coordinating among institutions whose primary function is to coordinate.

2.6.1 Organizational Design and Work Infrastructure

Magalhães [97] applies Pipek and Wulf's work infrastructures framework to organizational design, even viewing (to an extent) organizational design *as* infrastructuring. His own focus is primarily intra-organizational. He notes that while the two literatures are rarely put in conversation with each other, "organization design is tightly linked to the organization's information and software infrastructures." "Organization design" is formulated as "the ensemble of the artifacts created by management to mediate between the interests of stakeholders (mainly the shareholders) and the

day-to-operations of the organization." This brings to bear authority and accountability, policies, and specifications of information flows.

Magalhães claims that the ways information infrastructures link artifacts and immaterial elements have many similarities with "organization design" [97]. Organization design can even be thought of as "the materialization of the information infrastructure in the form of the organization's processes (including all strategic and operational routines and procedures);" and that "as a verb, organization design is as process for changing or bringing about improvement to the work infrastructure, a process akin to infrastructuring." In traditional organizational theory, the activity of designing organizations and supporting systems is a top-down endeavor, or "planning mode." The "situated mode" approach claims that organizations are in continuous process of being designed. This continuous change, as Magalhães says, explains a great deal, but it's still true that environmental conditions and managerial choice still "dictate many of their basic design features."

The author identifies a two-way connection between changes in work infrastructure and organizational design. That is, "Insofar as many ongoing changes in organization design are enabled by concurrent changes in work-related infrastructures, it can be assumed that information infrastructuring activities also underpin organization design activities" [97]. This prompts an observation about (organizational) power in (technological) infrastructuring, one which is perhaps more obvious in design fields more explicitly connected to empowering workers. The ability to which "end users" can engage in consequential design-in-use is related to the organizational design: it gives or denies participants the agency to undertake those changes and allow them to propagate and have effect. The organizational design shapes the channels by which the innovation is propagated.

However, Magalhães's embrace of the work infrastructure concept may have led him a step too far: "[G]iven the fact that most of the organization's information flows are now-a-days supported by software infrastructures, the information systems infrastructure and the organizational infrastructure tend to become one-and-the-same" [97]. While I am a proponent of analytically investigating the many ways an organization (or multiorganization) imbricates [94] with its technologies, I believe there is a danger in too extensively equating them. For example, technologies may be externally affected by vendor changes (recall the "double infrastructure" notion as discussed above [66]), and organizational changes as a result may be minor or non-existent. Likewise, organizational changes may or may not have robust technological analogues.

Magalhães brings the notion of the "point of infrastructure" from Pipek and Wulf to highlight a significant weakness in traditional organization design: that while such "breakdowns" and "reverse salients" happen all the time in the actual operation of organizations, there is no robust theoretical mechanism for accounting for either breakdown or innovative infrastructure use [97]. As a further complication in a multiorganizational design setting, *different* forms of breakdown are visible to different stakeholders all the time. One puzzle is what can make it possible for them to surface such issues to their operational partners in a meaningful (and not internally risky) fashion. What forms of stakeholder input can be legitimized (from lower level people) and turned into designable language and structures isn't addressed much in this work. In that sense, it still exhibits a certain managerial conservatism in its outlook. For example, consider one of the proposed remedies: "In a real organization, there will be many points of infrastructure occurring on a regular basis. What organizations need to do is to create policies and procedures for dealing with such events and for turning them into infrastructuring or designing opportunities." Policies and procedures are a part of effective infrastructuring, but as CSCW scholars like Pipek and Wulf have identified, are only a part of the many formal and informal tactics that are drawn upon.

2.6.2 System Design and Cosmopolitan Attitudes

Informal coordination may be common, but how acceptable and open it is can vary. Chisholm notes that there are conditions where informal inter-organizational structures become culturally acceptable to work within. These so-called "cosmopolitan attitudes" arise over time as people habitually meet with each other and learn about the other organizations, and come to understand their coordination problems from a "regional perspective" instead of only from the "parochial perspective of their own organization" [25].

From a CSCW perspective, synergizing, as elaborated by Bietz and Lee [13], happens commonly in infrastructural projects, where collaborative efforts can yield collaborative "economies of scale." In the terms of administration and political science scholars, their intensive collaboration can reduce the higher-level "coordination costs" that make coordination effective. Synergizing is different from local articulation and metawork [58] in that it is concerned not with modifying or coordinating an existing common field of work [133], but with *creating* that common field of work

by reconfiguring the connections and relationships between people and groups. The cosmopolitan attitudes people develop over time can make activities like synergizing more socially and politically feasible; but there would need to be enough common experience to create those attitudes, in order that the common field of work could be created. These complex cycles of structure-building and relationship-developing are important for understanding a phenomenon like the VCC and SAJOG, but challenging to disentangle.

2.7 Underlying Theories of Ontology and Process

What actually *is* a traffic incident? Does it have a single identity? What manners of things comprise the VCC/SAJOG multiorganization? How much of it is fashioned by interactions with systems, and how much of it lives in the hearts and minds of the people who interact with it? Weighty issues of identity and ontology will affect my analysis in substantial ways. So before concluding this literature review, I will briefly comment on how I will approach them. Generally speaking, I will take a sociomaterial approach to the onto-epistemology of the VCC project.

Two primary epistemological frameworks tend to undergird sociomaterial inquiry: critical realism and agential realism. Elaborated by Barad [8], agential realism (also sometimes characterized as a "relational" or "becoming" ontology) is an epistemo-ontological position that denies the outward reality of readily identified social and material "things" or even clearly delineated subjects and objects; rather, when we analyze phenomena, we make "agential cuts" that allow us to describe something as social or material, or understand how agency is enacted in a particular situation. "Agencies" are retrospectively constructed. Hultin further explains, "From this perspective, the human and the material are not pre-formed substances and their relationship not limited to a dualistic interaction. Rather, the relationship is one of entanglement, in which the human and the material are an ensemble of continuously performed intra-relations" [71]. Leonardi further elaborates, "When adopting the standpoint that observers – or 'knowers' as Barad calls them – are co-authors of the phenomena they are considering, agencies are seen to be products of the knowledge-making process as opposed to properties of any specific actors. For this reason, Barad takes the further step in arguing that agencies themselves are the product of observer-phenomena relations" [94].

Critical realism, meanwhile, does contend that the social and material do have some kind of

distinct ontological separation, though analysts and human actors may not (in fact likely do not) always have direct access to it, or they may have systematically varied perspectives on it. Advocates of critical realism see the social and material coming together and shaping each other via processes of "imbrication," or "the gradual overlapping and interlocking of distinct elements into a durable infrastructure," where "[o]ver time, the material and the social become the sociomaterial through the process of imbrication and stay conjoined through continued imbrications" [94]. "Structure" and "action" are put into conversation with each other, and that through the different kinds of agency exerted by the social and material, "the materiality of a technological artifact affords certain uses and actions" [94]. The trajectory of Orlikowski, a major influence on CSCW and one of its great exponents of sociomateriality, aligns more with the agential realist approach [112], while Leonardi's aligns more with the critical realist approach.

Sociomateriality as an analytical (and epistemo-ontological) approach has grown and changed over time. Gaskin, et al. have critiqued the often limited approach in STS to studying "idiosyncratic appropriations and the constant 'remaking' of digital technologies within local contexts (Kallinikos 2011)" [55]. In language that would be familiar to infrastructure studies scholars, they lament that "the emphasis of inquiring only within idiosyncratic local negotiations, however, may overlook what might be common patterns of activity and sociomaterial associations across multiple contexts." For them, the "new frontier" of sociomaterial research is instead about finding "latent regularities" in observed patterns of association between digital and digital elements across different contexts [55]. This in particular means studying organizations over time, watching attentively for "organizational routines," which are a "repetitive, recognizable pattern of interdependent actions, involving multiple actors." They are observable (or at least empirical) phenomena that can be viewed as sociomaterial assemblages. Scholars may then, according to this vision, begin to generalize theoretical findings through articulating an "analytic language" consistent with a sociomaterial ontology, according to a set of analytic categories [55]. This allows detailed qualitative data to inform comparison across contexts, which then can lead to theoretical generalizations.

In CSCW, meanwhile, the flexibility of a sociomaterial lens can enable scholars simply to say that both social and technical factors influence a context of study; it does not necessarily force many onto-epistemological commitments. In this work, I have attempted to closely attend to the interplays of agency and structure, of the social and material, in constituting the context

of study and the design spaces both the operational stakeholders and designers contended with. The particular (and to a certain extent, I confess, "idiosyncratic") trajectories of imbrication at different scales (for individuals, within organizations, and across the multiorganization) are meant to be meaningful and explanatory.

Chapter 3

RESEARCH SITE AND ENGAGEMENT

3.1 Introduction

I will now give a detailed description of my research site: the component agencies, the relationships they have around traffic management and infrastructure, the timeline and history of the project, the VCC design team's engagement with it, and my own experiences as a designer/researcher.

The Virtual Coordination Center project was meant to serve those who participate in managing significant traffic-impacting incidents in the Seattle I5 corridor. This includes agencies operating at the state, city, county, and regional levels. While my field site in its largest conception is grounded in the transportation systems of the greater Seattle region and the varied work that keeps them moving, it does not have one single physical or organizational identity. Rather, it is a constellation of many people and work places, where countless technology systems are used to support many kinds of work related to traffic incident and congestion management, along a general "corridor" of Interstate 5 in and near Seattle. This general configuration is sometimes referred to as a "multi-site" ethnography [99], though the goals and framing of the project were not strictly ethnographic.

3.2 History of the Field Site and Project

This dissertation's field site developed over a course of a few years. Several organizations that play a role in traffic incident and congestion management in the Seattle region began regularly meeting in 2017, after a few particularly disastrous traffic incidents caused them to realize that their existing, often ad-hoc, forms of coordination were not sufficient to clear major incidents in a reasonable amount of time. The notorious "Ride the Ducks" crash on the Aurora Bridge in 2015 [1], which lasted nine hours and claimed four lives when an amphibious tour vehicle collided with a charter bus, quickly entered Seattle traffic management lore, and was both a major inciting incident and a cautionary tale of considerable cultural importance in the collaboration that gave rise to the

[1] https://www.seattletimes.com/seattle-news/ride-the-ducks-vehicle-collides-with-bus-on-aurora-bridge/

VCC.

Since then, what is now called the SAJOG (Seattle Area Joint Operations Group) has held regular meetings of representatives from its member agencies, typically focused on discussing recent major incidents and upcoming projects, and finding ways to improve practice. The development of the VCC was a large part of its operation, but its regular meetings have always included non-VCC components, including giving construction updates, notifying members of upcoming events, and preparing for transportation-impacting winter weather.

3.2.1 Participating Organizations

While exactly who is involved in a given major incident can and does vary, the core participating agencies of the project, and its initial expected user base, were generally understood to be:

- The Washington State Department of Transportation (WSDOT): The state agency that manages state and federal highways, responsible for monitoring and maintaining these roadways.

- The Washington State Patrol (WSP): The primary law enforcement agency with jurisdiction over the state and federal highways.

- King County Metro Transit (KCM): Primary operators of the King County's main bus services.

- Sound Transit (ST): Primary operators of regional light rail, as well as some bus service. They operate across the general Puget Sound region, primarily in King, Snohomish, and Pierce counties.

- The Seattle Fire Department (SFD): The primary fire and emergency service operating within Seattle, including on parts of state and federal roadways that lie within Seattle city limits.

- The Seattle Police Department (SPD): The primary law enforcement agency with jurisdiction over the Seattle area in general. They may defer to WSP on incidents that occur on state and federal roadways within Seattle, or share responsibility.

- The Seattle Department of Transportation (SDOT): WSDOT's counterpart at the City level, managing arterials and other city-owned roadways and services.

SAJOG has included members from a few other agencies and organizations, such as the Northwest Seaport Alliance and Seattle Emergency Management, but these other agencies have been less actively involved in the VCC project specifically, and thus will not be discussed in detail. All the agencies and individuals in the Seattle Area TIM-CM (Traffic Incident Management-Congestion Management) community who participated at all in the VCC project, to whatever limited degree, form what I will refer to broadly in this dissertation as *operational stakeholders*.

In 2018, members of this SAJOG from primarily the seven core agencies began working toward a shared platform for collaboration primarily around major incidents, to be called the Virtual Coordination Center (VCC). The University of Washington's Center for Collaborative Systems for Safety, Security and Regional Resilience (CoSSaR) was involved in these discussions from early days. The Principal Investigator's established research partnerships with the participating agencies paved the way to CoSSaR becoming quickly involved with the design implications of these agencies' meetings. My own experience has been centered in CoSSaR and my years as a research assistant there, but has also included significant engagement with people and settings at the partner agencies. While early design work, prototyping, and capacity-building for the VCC began as soon as 2018, the project was greatly accelerated when it received a large grant [2] from the US Federal Highway Administration in 2020. A regional consortium of major employers (Challenge Seattle) also contributed financially to early phases of the project, and members of a University technology transfer office attended many VCC activities partly on behalf of Challenge Seattle.

When I speak of the "VCC design team" in this dissertation, I refer not only to the members of CoSSaR who participated in the project, but also the other University of Washington students who occasionally participated in short-term research projects, and the members of the software design consultancy Pariveda, who provided the majority of the technical design and software development of the VCC system. A leader at this agency was brought on in the early days of the project (in 2018), serving as the technical lead for most of the project, and the development team included between one and three software developers from Pariveda at any given time.

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[2] https://www.fhwa.dot.gov/fastact/factsheets/advtranscongmgmtfs.cfm

The design team used a modified agile development approach and human-centered design philosophies to co-create the VCC with the expert operational community. SAJOG meetings and VCC design work were primarily conducted remotely since the start of COVID, but included more in-person activities such as in-situ observations of VCC prototype use with some of the future users. The design team has, at different times, included several full-time personnel and part-time graduate students, meeting multiple times per week. Functional sub-teams included project management and planning, technical design (including user story writing), Concept of Operations (the preparation of a core policy document), evaluation and assessment groups, and others as needed. The system ownership was formally handed over to the Washington State Department of Transportation (WSDOT) in September 2023, following successful legislative action to expand the program.

Individual participants' involvement was dynamic. Some individuals were heavily involved in ideation, decision-making, funding, and other such actions since the SAJOG collaboration's inception. Other individuals joined and left from time to time. It is also common for individuals who held one job at one agency to take a new job at a different partner agency, and come to represent a different constituency within SAJOG. As people continued to engage, their own beliefs, desires, and ambitions for what the VCC could be and do for them have had noticeable impacts on its design discourse. Throughout, the VCC project teams had to attend to, interpret, support, and even sometimes tactically leverage these dynamics. In CSCW's Model of Coordinated Action, "turnover" is one of the dimensions used to analyze a coordinated action [92]. This kind of turnover, which sometimes behaved more as a form of circulation at the multi-organizational level, contributed in its own unique ways to the context of the project.

3.2.2 The Roles of Design Approaches in the Project

The VCC is a design project as much as it is a research site, and it cannot be understood without taking that structure into account. Concepts and techniques from human-centered design [30], Agile design [138], participatory design [38], action research [64] and participatory action research [103] influenced the practical work and philosophical approach of the project. These approaches were used in various ways, sometimes quite different to their standard methodological specifications. Design approaches were used rhetorically and memetically, as well as in the production of artifacts.

Because the VCC as a research project was not conducted with the goal of rigorously applying, or critically evaluating, any particular design methodologies, I will not be explicitly evaluating a program of design research or design methodology in my dissertation. Rather, I primarily use "design" as a kind of ethnographic lens on what actually went on in the project, and how the many different actors–design team and operational stakeholders alike, certainly including me–explored ideas, acted strategically, and tried to bring change to fruition. This range of concerns also echoes Pipek and Wulf's broad conceptualization of design both before and during the use of systems. Therefore, I will use their own broad, user-centered and evolutionary concept of "design" to look at a few ways "design" can be understood at the organizational, political, and social levels. In the Methods chapter, I will further elaborate on how different design approaches and philosophies can be brought to bear on the issue of studying the VCC project, and of reckoning with my very rich but very messy involvement with it.

3.2.3 My Engagement with the Research Site

The variety and duration of my roles in the development and analysis of the VCC system, starting in 2018, give me a great deal of perspective as a human-centered designer and ethnographer, allowing me the opportunity to engage with this project in a uniquely nuanced and detailed way. My project contributions have helped me to obtain and sustain a higher level of entrée [52] than is common in the often cautious and insular world of government organizations. I have been able to directly observe and participate in the pipeline between stakeholder operational activities and the creation and promulgation of system elements, and the impacts of real-world use of those elements. Nevertheless, this often "messy" [88] relationship also makes it difficult to disentangle both my own analytical perspective and what counts as data collection. Navigating how to authentically and rigorously engage the often (understandably) cautious agencies is a delicate task, particularly when these stakeholders are trying to innovate their practices and technology uses. I have tried in this dissertation to attend to the "meta-methodology" of how I approach my own relationship with my empirical field site and the form and nature of its data collection. I expand upon this attempt in the Methods chapter.

3.3 The Virtual Coordination Center (VCC) System

The VCC is a web-based cloud application with users from across SAJOG's participating agencies. Some entities that occasionally engage with SAJOG and may even attend its meetings (such as the towing company the City of Seattle contracts with) do not yet have active system users. Some key SAJOG agencies like the Seattle Fire Department were expected to have several active users but have as yet been reluctant to be directly involved. Thus, there is very significant overlap between the SAJOG roster and the VCC userbase, but they are not one and the same.

3.3.1 Interface Overview

It will be important both for clarity and for accountability to the system-building focus of CSCW scholarship to describe the VCC system itself. The home page of the VCC, the Dashboard, provides a quick view of the current state of Seattle area transportation conditions. It contains three primary components: the Integrated Dispatch Feed, the Situation Map, and the VCC Incident cards.

Figure 3.1 shows the VCC dashboard as it appeared in October 2025. The Integrated Dispatch Feed (center of the page) represents a running tabular view of active records from the four CAD systems that feed into the VCC. Users can filter this table by how recently records have been updated, up to two hours. The Situation Map (left of the page) plots the Dispatch Feed records that have longitude/latitude coordinates associated with them on a regional map. The map contains several additional layers, such as traffic camera snapshots and live traffic conditions. The VCC incident cards (right of the page) show a small amount of high-level information regarding any active VCC incidents.

A user can click on an incident's card to go to the full collaborative incident page, called an Incident Model (IM). See Figure 3.2 for a sample Incident Model. An IM can be created by a VCC user, or automatically when certain kinds of records appear in the Feed, when a potential major traffic-impacting incident has begun. Users can create an IM from any dispatch event in the Feed, which then ports information from that event into fields of the new IM; or the IM can be created fully manually without any specific dispatch event. When an IM is created, users receive an email notification. The IM page has a map that looks like the VCC's general Situation Map, but with the additional ability for users to make annotations such as specific road closures. Users can update

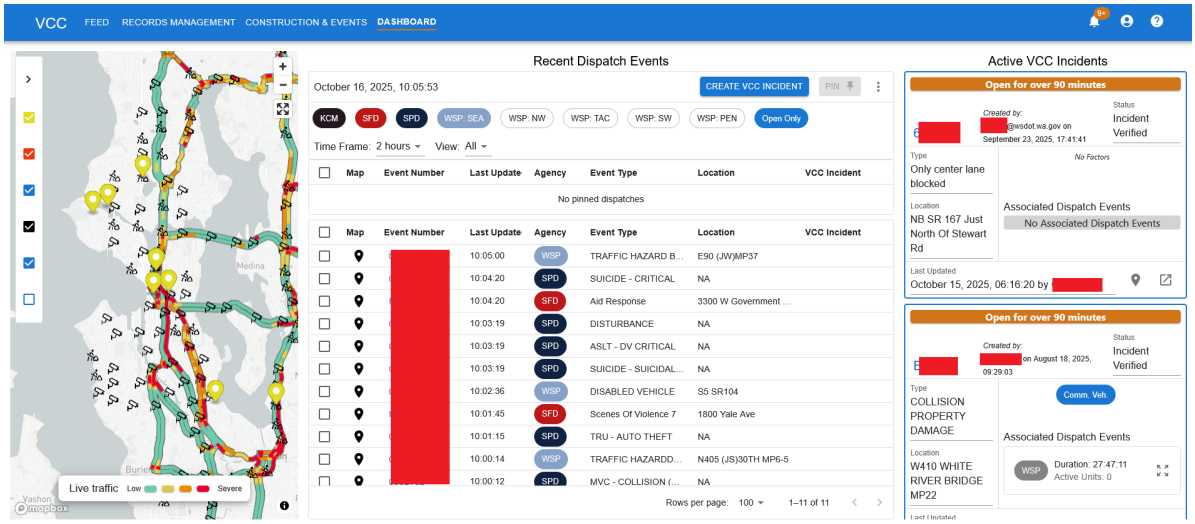

Figure 3.1: Screenshot of the VCC dashboard, with some information redacted

many information fields, such as lane closures, the current Incident Commander, and the incident's expected duration. It also contains a section for freeform notes; a tab for "mobility strategies" such as activating overhead message signs; and a tab for communications personnel to strategize social and traditional media postings. Even after incident creation, any number of dispatch events from any of the four CADs can be associated with the incident. All updates to fields are captured in a running log, which can be viewed by clicking "SEE ALL UPDATES."

Once the incident's work is completed, its status is changed to Closed, and it no longer appears on the VCC's dashboard, but can be temporarily viewed on a Records Management page by a subset of users. The Records Management section packages information from each completed incident into a .zip file that it sends out to all the participating agencies' data management teams. Each participating agency also has delegated administrative users who can see the administrative interface of the system, and add and remove users and grant user roles.

3.4 The Challenges and Opportunities Involved in Co-Creating the VCC

The VCC brings together a particular collection of data and practices for the first time, giving its operational partners more shared and symmetrical access to information than they have had

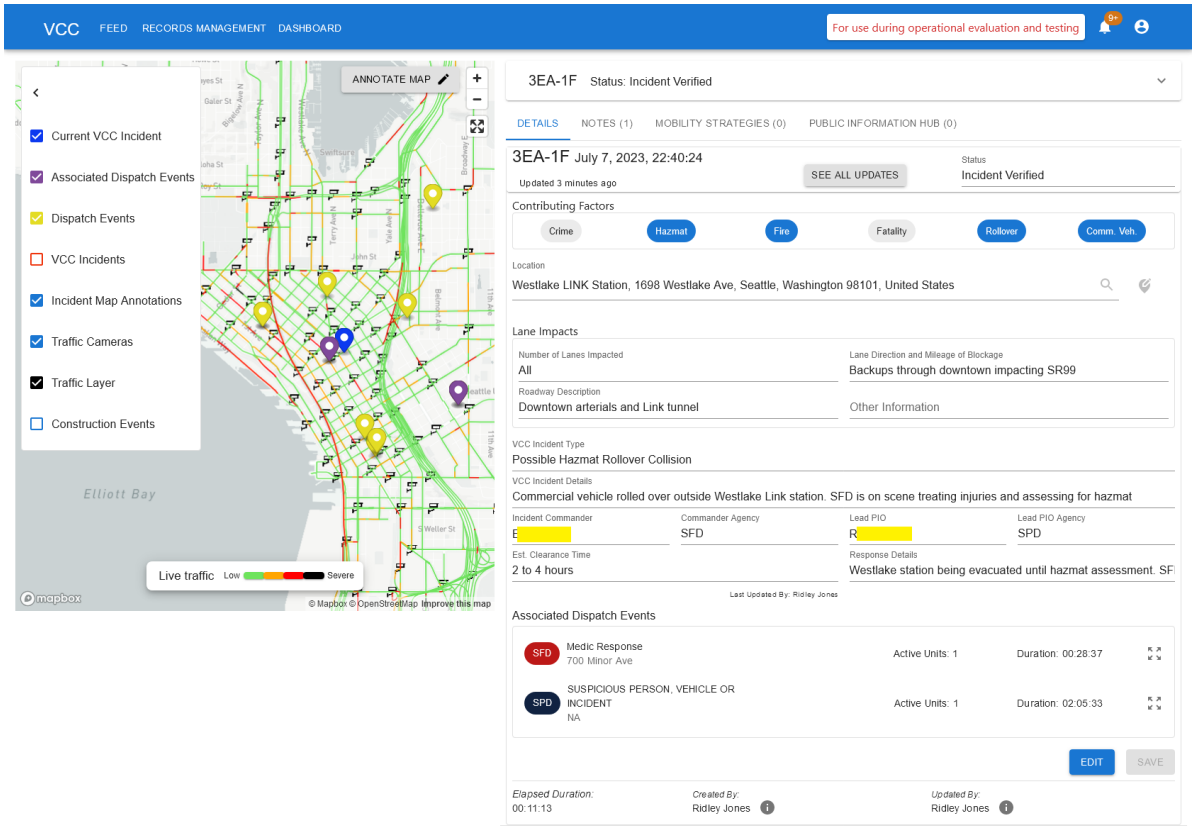

Figure 3.2: Example of a VCC incident model page, with some information redacted

before. The stated primary goal of the VCC is to enable better management of traffic emergencies and resulting congestion. It is also designed to be flexible enough to allow users to employ it for less severe issues that may emerge (such as planned closures of certain facilities, or more moderate traffic disruptions) if they desire.

The VCC is intended to allow first responders, traffic managers, and public information officers to collaborate more efficiently and effectively, perhaps even transforming inter-organizational emergency response for the Seattle area and beyond. Yet this flexible, effective, collaborative aspiration required a challenging organizational transformation that balances individual agencies' preferences and histories with new relationships and greater transparency. This is a challenge faced by many regions and large inter-organizational projects, and thus a site for significant learning and improvement.

Further, for the VCC's operational community, there is a general norm and oft-repeated phrase of "staying in one's own lane": not stepping on the operational or jurisdictional toes of other groups unless necessary. Clumsily "veering" into other such lanes can have significant negative consequences, but so can excessive gatekeeping and silofication. So, aspirational interdependence emphasizing shared problem-solving may be in some tension with "staying in one's own lane."

The VCC is, by and large, a success story. It currently has 450 registered users, with more expected as it expands. It is in daily use for many of these users. In 2025, 460 VCC incidents were created, with February and March having the most at 71 each. Its path to that success was, however, winding at times, and I believe both the unambiguously positive and more difficult parts of that path can be instructive. I hope to use experiences from this project to help CSCW, organizational studies, and human-centered design think more clearly about designing in this complex space. I will connect some of the dots between important concepts such as work infrastructure, coordination theory, and design research methods, putting them into conversation and extending some of their analytical lenses. I also hope to reveal both the challenges and the tremendous opportunities of working in inter-agency public service design settings. These are, to put it extremely mildly, challenging times for the "maintainers." Moving fast and breaking things has become the *modus operandi* for even many of our leaders, to often heartbreaking consequence. I consider it a critical part of this dissertation to celebrate the fascinating, critical, and honorable work of keeping public infrastructures and services running.

Chapter 4

METHODS AND METHODOLOGY

4.1 Introduction and Rationale

The VCC was a complex project to participate in, and an even more complex one to analyze effectively. It involved planning and undertaking many design activities, carefully orchestrating meetings with a wide swathe of decision-makers, refining interactive designs with developers, strategizing with the design team, pulling together different regulations and governance concerns, seeking and maintaining funding and partnerships, and (where possible) setting aside time and precious stakeholder access for research data collection. Here, I try to systematize my analysis of both project-specific activities and observations of operational stakeholder dynamics and work in such a way as to generate usable knowledge, while yet retaining fidelity to the messy [88] realities of what happened and how I participated in it.

To address my primary research question, *How can designing collaborative systems help interdependent public service stakeholders innovate their shared work?*, I first gathered the wide-ranging data I had access to from the VCC project. I then used multiple conceptual tools from qualitative research to refine this broad corpus into a usable dataset, and conducted initial analysis, which then was refined and complemented with a final round of data collection in the form of interviews in 2025. Before describing the methodological approaches I selected for curating, refining, and analyzing my dataset, I will first describe how the corpus it was drawn from was generated in the first place.

4.2 Data Generation and Collection During VCC Project

During the VCC project, a wide variety of data (broadly construed) were generated by many sources, using many techniques. Sometimes they were gathered in direct and instrumental service of the design project itself or its logistics or governance, and less frequently they were gathered for the purpose of doing academic research. In service of making an honest and nuanced account of

the VCC project, I begin by surveying how the data I eventually analyzed for my dissertation came into being, in their material and instrumental context. This included, but wasn't limited to:

- Workplace observations: in-context observation of people actively working in different VCC stakeholder agencies. The most common sites were the Washington State Department of Transportation's Transportation Management Center (WSDOT TMC), the Seattle Department of Transportation's Transportation Operations Center (SDOT TOC), King County Metro's Transit Control Center (KCM TCC). Several "ride-alongs" took place with responders at WSDOT Incident Response Team (IRT), SDOT Response Team (SRT), Washington State Patrol (WSP), Seattle Police Department (SPD), and Seattle Fire Department (SFD) in their response or patrol vehicles. In addition, one observation each were conducted at SFD, SPD, and WSP 911 centers. I conducted eighteen observations in 2019 as part of the development of the VCC concept of operations (ConOps), a formative policy and process document I co-led the writing of. These early observations were also used to investigate formative VCC concepts, and were used again later to evaluate VCC use *in situ*. Thirteen observations were conducted as a part of Use, Feedback, Refine (UFR)4 in 2022, of which I participated in five; five other UW design team members also participated, sometimes in pairs and sometimes individually. During the VCC's post-deployment evaluation period in 2023, ten observations were conducted by four UW design team members, which I did not directly participate in.

- Interviews: Usually semi-structured interviews were used at many points throughout the VCC development process, sometimes for background information about work settings, sometimes to gather feedback about VCC design elements, sometimes to learn more about an agency's procedures in more granular detail than would be possible in a group setting, and sometimes to evaluate VCC metrics and objectives.

- Design workshops: a wide range of activities bringing together groups, often inter-agency groups, of stakeholders to evaluate and play through designs under development. Occasionally, more formal field notes were taken of these activities. The primary design workshops that are included in my dissertation's data are a feedback session conducted in January 2021 with a broad range of operational stakeholders to provide initial feedback on the structure

of the VCC's integrated dispatch feed and incorporating both visual references to works in progress and real time polling using the polling tool ThoughtExchange; and four alternate route planning activities conducted in February-May 2022, spearheaded by a WSDOT leader who had previous experience designing alternate routes, and using operational scenarios to work through the possibilities for creating incident templates in the VCC. These four activities convened large participant groups spanning most of the VCC's participating agencies; and ancillary to these four workshops, smaller discussions were conducted with one or two people from each agency to go into depth on specific questions. Numerous other design workshop activities of various group sizes and levels of complexity were conducted throughout the VCC project, but these are the ones I sample in my data corpus.

- Surveys and other asynchronous data collection. This method was used in a few different ways. It was used to evaluate the VCC itself at different stages of design, with the most significant examples being a pre-deployment survey sent to prospective users in November 2022; and two broad satisfaction surveys sent to all VCC users shortly after deployment in April 2023, and again in June 2023 to identify any post-deployment learning curve or process changes. Asynchronous data collection was also used *during* VCC development, when we were trying to identify the characteristics of VCC incidents, so that the VCC's model of what an incident was would comport with the broad understanding of future users. For example, a subset of eight project participants were sent a spreadsheet in August 2021. On this spreadsheet, they were asked to document real incidents that occurred during the seven-day assessment period which they think would have qualified as "VCC-level" incidents if the VCC were available, and why. We were then able to compare their responses and reasoning, and use this information to update our own model of what we should include in the system. Numerous other smaller surveys were also used throughout the project, but were not analyzed directly as data for this dissertation.

- Internal traces: Data collection of user stories and other design-team-internal documents that included comments on Azure DevOps user stories in progress, draft Google docs with comment threads attached, and different potential versions of designs. The emphasis here is on

the internal comparison and discussion of items, allowing a partial reconstruction of the design team's varied and evolving thinking on both specific interface design issues, and conceptual challenges we worked on throughout the project. This form of data resembles Geiger's trace ethnography [57], but is more limited and specific, and unlike trace ethnography, is not meant to be the sole or primary basis for reconstructing an ethnographic context.

- Work artifacts: wireframes (low-fidelity visual representations of interface elements under development); meeting minutes; governance and policy documents such as steering committee charters, project management plans, and Concept of Operations (ConOps) drafts; a "system inventory" of relevant technology systems used across the agencies, and other items that documented project progress and enabled decision-making.

The list above represents much of the work processes and artifacts of the VCC project, where the UW and Pariveda design team tried to gather meaningful and extensible data, while providing clear design value. It does not represent the full and complete records of the VCC project, but I have selected what I believe offers sufficient depth and coverage to be a reliable and useful base for analysis. In the following sections, I will describe two very different structured ethnographic approaches for understanding and theorizing on design situations while simultaneously participating in them. For researcher-designers this is a challenging balance to strike (or tension to navigate)– endemic to some extent to ethnography in general [49] but requiring special attention in projects with both social science and design goals. I will describe some of the values and commitments of each approach, and connect them to the process of developing the VCC and creating, structuring, sharing, and making use of the broad range of its data. This will allow me to contextualize the nature of the corpus I gathered for analysis in this dissertation. As each approach has its own guidelines for research quality, each can also offer some ways of understanding different types of VCC data and research/design activities, even if the data were not collected explicitly under a given methodology's guidance.

Design Ethnography and Related Approaches

Design ethnography is one important methodological approach that marries design methods with longer-term ethnographic analysis. As Baskerville and Myers [10] describe it, design ethnography

is an evolution of two strands of research that have historically connected ethnography and design. The first they call "ethnography for design" or E4D. It arose in the 1970s, when designers learned how useful ethnographic methods could be for learning about consumers [10]. This strand of work concerns the "broad patterns of everyday life" most relevant for developing new products and services, rather than deriving rich ethnographic or anthropological insights per se [10]. Conversely, ethnography to study design practices (E2D) aimed to ethnographically study designers and design processes themselves, as the rich anthropological subjects they are. Research through design, action research, and related approaches can be seen as a part of this larger body of work, where intervention is a means of studying a phenomenon, "faltering from ethnography to design," as it were [69, 10].

For Baskerville and Myers, what makes design ethnography distinct from these two other traditions is that in design ethnography, the ethnographer is "actively immersed and engaged in a setting where people are designing artefacts, producing artefacts or introducing artefacts into a social and cultural context." An underlying and animating belief in this way of researching is that there is a meaningful connection between the flow of real lived experience of a setting's stakeholders and how products might be better designed for them [129].

Different scholars practicing design ethnography may put more or less emphasis on producing tangible design outcomes or products. For example, Pink, et al. [116] claim that producing designs is not required. However, materiality generally speaking is more central to DE than it is for traditional ethnographies. There is a strong analytical value of prototyping–or actually creating design objects for consideration and refinement even if there is no final product deliverable–for DE. Prototyping artifacts is a way to probe "social and cultural values," and a recognition of the responsibility that comes with reflecting them or reifying those values.

In the VCC project, using design works in progress to engage with stakeholders was of course the bread and butter of our participatory, Agile-style process. But doing this also helped us to build the structure of our engagement with the operational stakeholders–a mutual education on how we on the design team would approach the process of discovery and concept development. An early example of this was a post hoc analysis of data generated in participating agencies' computer-aided dispatch (CAD) systems during a shooting in downtown Seattle in January 2021. After this tragic event, which of course generated significant activity from multiple first responder agencies, the design team obtained dispatch data from the sources we were hoping to use for the Integrated Dispatch

Feed (SPD, SFD, KCM, WSP). We obtained all the records from these systems that were generated in a time frame starting shortly before the shooting, and ending some time after. This allowed us to identify what information from the shooting came from each source at which times. This was meant to be a general proof of concept of the usefulness of the future Dispatch Feed. However, in doing so, we ourselves uncovered something unexpected. While King County Metro Transit (KCM) dispatch data is naturally more focused on bus movements and management, and thus wasn't considered as central to incident management as police or fire dispatch, it was KCM dispatches that first reported on the shooting. In hindsight, this made sense to us, since bus drivers have much larger and more persistent physical coverage of downtown than police officers or firefighters do. Showing this to the operational stakeholders cemented the importance of pooling their data, and being willing to seek broadly and creatively for new collaborative advantages, despite the potential risk such transparency could bring. It also helped us–the broad "us" of the operational stakeholders and the design team–come to see the bus operators as not just an occasional participant, but as a large network of valuable "human sensors".

In any kind of sustained design-and-research engagement, there is a process of gaining entree and establishing the relationship between researcher, context, and stakeholders, sometimes called "moving in" [10]. Baskerville and Myers identify a methodological difference between action research, participatory action research, and similar approaches; and design ethnography, in this process. Action research typically begins with learning about or formulating the problem space, whereas design ethnography more typically begins with "the immersion of the researcher into the design practices of the subjects (which may be in progress or ongoing)" [10]. The design ethnographer can use "designerly" ways of thinking and acting to bring new concepts and artifacts into the research setting, giving them perhaps the ability to probe [56] the thinking of the participants in ways more passive ethnographic observers could not.

In the VCC project, access or entree was not a thing that was achieved once and for all. In part because of the instrumental focus of the project, in part because of its general organizational complexity, and in part because of the resource-constrained and cautious nature of many of the agencies, access beyond very carefully structured activities had to be continually re-negotiated; and trust and value had to be re-demonstrated as well. For example, in 2019, I conducted workplace observations in several settings in service of the early ConOps work. This accorded me access to

sensitive workplaces like police vehicles where I did ridealongs and 911 centers where I did "sit-alongs." It yielded very tangible fruit for the VCC design project, in terms of tracing data journeys from their origin in call centers to their expansion and evolution on incident scenes. My initial findings about other agencies' or work settings' practices also became a kind of social currency *during* observations; people always wanted to hear about my other experiences or how other people "did things." However, the curiosity and excitement were always in dialogue with other constraints, such as the time and attention of participants or the safety issues involved in allowing me full access to incident scenes.

Many of us on the design team had our own agendas and preferences for how collaborative systems should be built and used; we approached the project, after all, with conditioning from our research and professional backgrounds, and we were already quite "bought in" to these approaches. This realization led me to ask questions in my 2025 interviews (described later) about design team members' preferences and reflections of their own design goals in dialogue with stakeholder preferences and goals. It also led me to attend to and gather trace data from Azure DevOps, the system we used to manage the software development work. A given "user story" (a statement about a system element to be developed, such as a specific function or interface component) would often have back-and-forth from different team members in the comments, clarifying requirements, advancing different options, or working through technical constraints. Yet most of us were also the *constituents* of the agencies. Most of us lived in Seattle. We ourselves used the roadways. The relationships we built with the participants allowed us as community members to gain additional perspective and sometimes advance information about traffic conditions and management, which affected all of us as travelers. This helped build the complex web of trust, information-sharing, and reciprocity we developed and re-developed with the operational stakeholders.

Because the activities of Design Ethnography are multifaceted, the processes of data gathering and the forms of the data vary considerably. Design Ethnography may include data gathering directly connected to more practical concerns like questionnaires and UX tests. How to analyze such artifacts as research data is a challenge for design ethnographers. A disciplined design ethnographer has a keen anthropological awareness of the semiosis of data gathering and what data are legitimized for decision-making by social practice. We dealt with many of these same tensions and challenges in the VCC. Many of the most interesting data-gathering procedures we conducted, such

as surveys about the trustworthiness of the VCC or conceptual meetings about the ConOps and their "operational scenarios," weren't organized in reference to each other, making it somewhat more difficult to draw clear explanatory connections between them.

While, as mentioned, the VCC project did not take a deliberate DE approach, I see harmonies with some of its goals and activities. We intentionally sought to use emerging VCC functionality to study coordination between actors (rather than only meeting their stated coordination requirements). The ways we used interface functionality to probe coordination was at times confusing or frustrating for operational stakeholders, as it didn't conform to their typical experience with system design. We would put partially functioning prototypes in front of them and ask them abstract counterfactual questions about how a complete version might connect to their future collaboration–not an easy task. Design Ethnography gives some structure for understanding why this was valuable in the longer trajectory of the project's work, and even served our aim to co-create the system with operational stakeholders.

Biography of Artifacts and Practices (BOAP)

Another compelling model for studying complex design projects over time is the biography of artifacts and practices (BOAP), which came originally from the usually more theoretically oriented world of Science and Technology Studies [72]. The history of BOAP is, in part, one of trying to find ways to overcome frustrating limitations in the empirical approaches used in STS projects [72]. It was driven by dissatisfaction of STS research that fails to live up to its own aims due to simplistic and limited research approaches. Importantly, BOAP is a "methodological (and in that capacity in part meta-theoretical) approach to the study of sociotechnical change" [72].

Sociomateriality and activity theory both contributed to what would become BOAP. The idea of an artifact having a "biography" was a metaphor drawn from the sociomaterial approach to understanding "the extended and evolving nature of innovation that takes place at multiple sites and times in which, for instance, software applications in manufacturing and the service sector became shaped" [72]. Activity Theory, meanwhile, was used to investigate "how Health technology innovations were shaped in networks of 'activity systems' and, in turn, how the involved organisations and practices evolved in the process" [72].

BOAP's interest in temporally and spatially extensive research sites creates a great deal of complexity and variation. As such, rather than provide a single definition of or procedure for BOAP, the authors outline eight minimal "inclusion criteria" or characteristics that indicate a study is doing adequate BOAP (which I will not describe in detail). These characteristics generally prescribe sufficient spatial and temporal reach to give an empirically adequate account of the studied phenomena, and to pay particular attention to "interstices" of action where meaningful and interesting change is likely to happen. They also take an "ecological" view of the interconnected human and non-human actors in the situation, which mutually shape each other in a materially salient way (and which mutual shaping may prompt an adjustment to the research approach itself).

In the VCC's setting, parts of this ecology were more visible than they may have been in other settings. Yet while the VCC project is genuinely unusual in the persistence and depth of the access we *did* have, we still only got part of the story. Each agency had many different internal dynamics of risk evaluation, funding, and decision-making that we only heard about secondhand. We did not have full access to the power structures of each agency, and those we did have access to were cognizant of the delicacy of being fully candid about those internal dynamics. This sometimes led to what *looked* to us like rapid changes in an agency's strategy with respect to the VCC–often an unexpectedly "sudden" favorable swing following months of hesitancy.

To tame without flattening the growing variety of data to be analyzed, Hyysalo, et al. recommend "a recursive movement between different data-sets and different sampling strategies to examine data at different grain-sizes."[72]. Such complexity in data, data gathering, and analysis may often require a group approach–allowing different researchers to tackle specific domains of the project and allow some temporal flexibility [139]. People inhabited the role of "researcher" and "designer" in highly varied ways and supported each other's efforts just as heterogeneously. For example, members of the Pariveda design consultancy who worked on the project sometimes advanced conceptual approaches to the project that captured their interest, such as the ability of a "pre-planned play" (name given to a potential VCC component, consisting of incident "templates" that could be activated under certain circumstances) to advance collaboration. They also repurposed my ethnographic field notes to extract design guidelines. Regarding field notes themselves, the workplace observations and ridealongs I conducted during 2019 ConOps work eventually bled over into our standard data gathering approach when evaluating the design of the VCC (in the VCC's

post-deployment evaluation, which included situated workplace observations). Further, members of the UW team whose job descriptions were primarily administrative occasionally participated in both research and design activities, as their own interest and availability led them–including conducting some of the workplace observations of the Evaluation period (beginning as soon as the system's earliest adopters were given user accounts in late 2022, and continuing until the system was handed off to WSDOT in September 2023), and writing training materials. While there was no conscious effort to follow a shared discipline of data gathering to cover the research context in this particular BOAP fashion, there were also many "hands" involved in many different aspects of data gathering and analysis, which contributed greatly to its richness.

4.2.1 Conducting the VCC Project in Practice

Since the VCC design team was centered at the UW department of Human Centered Design & Engineering, we were able to use a particular repertoire of techniques and rhetorical tools for doing the complex design, investigation, and organizational work of the VCC project. At times, specific design approaches and philosophies–particularly participatory design [36] and human-centered design [30]–directly influenced how the UW design team described the work we were doing and how we communicated about our design approaches to stakeholders and funders. Wording emphasizing participatory values, an intellectual framework of sociotechnical system development, and the Agile-style process of inquiry we planned to use were sprinkled across grant applications, policy documents like the ConOps, and persuasive presentations to stakeholders and potential partners.

At other times, ethnographically inflected approaches were able to be introduced due to the institutional academic legitimacy we brought to the project. For example, we were able to make a case for doing workplace observations in order to prepare the early stages of the ConOps. Embedded workplace observations were also later used for project evaluation and user acceptance testing, as they were already somewhat socialized in the project. We were also permitted to interact with frontline and lower-powered workers and foreground their stories and concerns to some extent, though this usually required significant time and effort to set up.

In this assessment of approaches to long-term design-oriented research, I have used the social/ethical values, conceptual foundations, and methodological guidelines of specific approaches

to describe how the actual work of the VCC as a design and research project took place. Some emphasize the importance of thinking with tangible design products as a critical window onto and provocation of unfolding social practice, such as the materiality emphasis of DE or the STS focus on artifacts' agentic lives in a research setting. Others require particular examination of certain types of phenomena (e.g., dynamics across temporal scales, designers' own motives and impacts). Some follow very specific types of commitments to specific types of engagements with stakeholders. The VCC was not organized according to any one structured methodology, so the previous sections should not be taken as an attempt to critique the VCC as a methodological "failure" or departure from a standard. Since the primary goal of the project was to achieve a useful working system rather than to evaluate or abide by a particular conceptual or methodological approach, it adapted over time to the constraints and opportunities that were presented to it. Instead, reviewing these approaches has enabled me to better explain the production of artifacts, knowledge, and relationships of the VCC project as an object of study, which then allowed me to make my analysis process described in Part 2 clearer and more traceable.

4.3 Part 2: Research Analysis Methods Used in Dissertation

4.3.1 Data Analysis Overview

When I began my dissertation, I faced a couple of specific analytical problems that my analysis methodologies would need to help me address. First, of course, I needed to be able to distill data of highest relevance from my corpus to answer my research questions. Second, I needed to be able to map out identifiable themes in the very heterogeneous data sources I would be using. And third, I need to reckon with the "messiness" of the VCC enterprise and the forms of my engagement with it.

To address these issues, I followed a multi-step process. First, I used tools from Situational Analysis to map out my initial data corpus and better understand its structures and components, and what the relevant actors and connections between them were. This helped guide me in distilling the corpus into a dataset for analysis. I then primarily used Thematic Analysis to analyze the dataset. While iterating my Thematic Analysis of my existing dataset, I performed a second round of data collection in the form of semi-structured stakeholder interviews in early 2025. I did this to

1) assess some of the changes in VCC usage over time (since my extant dataset ended shortly after full deployment); 2) compare my own experiences with others on the design team; and 3) explore and refine some of the analytic themes in progress I was developing.

4.3.2 Data Corpus Refinement with Situational Analysis

To winnow down my first-stage corpus to a manageable dataset, I employed a situational Analysis "messy map" [27] exercise to map out aspects of interest, with a general focus on concepts related to shared work infrastructure, the formulation of needs, and stakeholder interdependencies and histories. Thematic Analysis (TA) is quite common in CSCW [48], but SA is less so, so I will give some background on the approach.

Situational Analysis evolves prior work on grounded theory development by centering the creation and careful iteration of different kinds of "maps": visual depictions of aspects of "the situation" [27]. Importantly, a strong adherence to the theoretical framework through which Situational Analysis was developed rejects the notion of a research context. Rather, everything relevant to understanding the situation is within the situation itself; and a key part of the analyst's task is to figure out what really contributes to the situation per se. This aligns with the constructivist assumptions and epistemologies inherent in Situational Analysis, which strives to push its emphasis on situatedness beyond Glaser and Strauss's, from "conditioning" to a primary object of analysis itself [27]. While I am not entirely convinced that everything relevant to understanding the VCC is within its "situation" (whatever that might end up meaning), understanding context as constitutive and worthy of direct study is useful as an analytical principle in this project.

The first type of map are "messy" situational maps that "lay out the major human, nonhuman, discursive, and other elements in the research situation of concern and provoke analyses of relations among them" [27]. As Clarke explains, they "capture and discuss the messy complexities of the situation in their dense relations and permutations" [27]. In addition to the messy map, there are social worlds/arenas maps and positional maps, which I did not substantively engage with. Below, under section 4.3.5, I explain how I used messy maps in more detail.

4.3.3 Data Set Curation

One of the major challenges for studying the VCC project is the volume and variety of its potentially applicable data. Formal or personal notes at given meetings, email conversations, design sketches, comments on regression tests, grant proposal documents, interview transcripts–all these and more helped form the broad corpus of VCC project data. Most of these data–plans, meeting notes, document drafts, images, survey responses, and interviews–were stored in a project Google drive, which I downloaded prior to beginning my analysis. User stories, regression tests, and technical documentation were stored in an Azure DevOps project, which I accessed during my analysis and downloaded specific items as needed. Most visual mockups were created and stored in Mural (a collaborative whiteboarding tool) or Figma (a UX design tool). I accessed and downloaded specific items from these tools as needed. I acknowledge that there were items that may have been deleted prior to my obtaining them, or only recorded on individuals' personal computers. This overall set of data for the project which I began with, as large and varied as it is, is necessarily incomplete.

Reckoning with heterogeneous but rich data has been noted as an issue in design ethnography and BOAP, for example [129, 72]. Many people contributed to generating this data, and my own involvement varied: and I created many of these artifacts, edited or commented on others, and only viewed others.

As part of my commitment to reflect on the nitty-gritty design work, I include both more official documents (cleaned meeting minutes, design presentations, user guides, and the like); and, where available, backchannel information such as comments on documents, tracked changes on drafts, and back-and-forth in user story pages. This helped to surface some of the contemporaneous strategies, frustrations, and goals that the design team engaged in. In turn, this helped inform my interview protocol and approach for recruiting interviewees; for example, questions and doubts on the part of the design team about the current state of the operational community's collaboration informed the design stakeholder interview question *"What roles did the design team play in helping the operational stakeholders think through what collaboration meant to them in the VCC system and project?"*

4.3.4 Selecting Data for Analysis

The VCC's stakeholders have significant and complex experience using a variety of work infrastructures owned and operated by their own agencies, to do their traffic incident and congestion management work. As they work across agency boundaries in various capacities, and particularly as they have been working toward the development and rollout of the Virtual Coordination Center, the "devices, tools, technologies, standards, conventions, and protocols" [117] they use—including, as we hope, the VCC—change and develop. The dependencies of these work infrastructures become more complex as they cross organizational boundaries, and the improvements people make to their collaborations can be variously scaffolded or obstructed by their work infrastructures.

Part of pursuing my research questions meant acquiring a basic grasp on stakeholder relationships to existing work infrastructures. I was drawn to data in the VCC project that could help elucidate changes in "embeddedness" or "installed bases." I have also striven (within the limits of my access and available data) to further differentiate between agency-internal changes catalyzed in some way by the VCC (such as an agency beginning to use VCC as a replacement for an internal system being deprecated), and what is changing in the VCC's "interface" between the agencies (such as VCC incidents being discussed as a routine part of SAJOG meetings).

To facilitate analysis, I have roughly divided the VCC project into "subprojects," each representing a key strand of work. These "subprojects" often do overlap with others in time, participants, and goals, but drawing some boundaries is useful for the sake of analytical and narrative clarity. Fully investigating every subproject would be infeasible for this dissertation, so I selected a subset of these subprojects to focus on.

When selecting subprojects to include in my initial dataset, I considered a few other general criteria.

- Good temporal coverage of the project (that is, the corpus as a whole should span a wide time range, starting well before the concrete VCC interface development began).

- Richness and completeness of a subproject's data available for analysis (though I do not claim to have all possible data for any of the subprojects).

- My own level of involvement in collecting the data, or closeness to the work being done (more

involvement being better, all else equal; while I took on many roles in the project, my focus was not always in all places equally).

Below, I briefly describe each selected subproject and some of the additional rationale for including it.

Concept of Operations

The Concept of Operations subproject involved planning for and preparing the VCC's Concept of Operations (ConOps). Concepts of Operation are project documents typically written at the beginning of a systems engineering project to identify how a future system or operation should work. However, the VCC's ConOps was developed in an idiosyncratic fashion over several years, beginning in the summer of 2019, halting in 2020, and not being complete until well into the VCC's development cycle in February 2022. The work on the ConOps was led by UW design team members; I was often a co-lead on this work. The ConOps work in 2019 was briefly co-led by a City of Seattle executive, who left his position several months after. Especially in the first few months of the ConOps work, we experimented with many different ways of structuring the document, and there were, at any given time, multiple drafts in progress, each of which we on the ConOps team used to advance a different vision of the ConOps and what role it should play in the project. I discuss this in greater detail in a recent paper [77], but what the reader of this dissertation should take from this digression is that I occasionally quote different versions or drafts of the ConOps from different points in time or primarily authored by different people.

The ConOps work in general engaged with a somewhat different subset of stakeholders than the more interface-oriented work of the VCC did (e.g., a slight bias toward compliance and executive stakeholders). It is therefore valuable just for this reason. Its focus on principles of collaboration and coordination, and how the VCC might play a part in that, gives it unique value in the corpus as a whole. Certainly, extensive discussions about collaboration and coordination took place before ConOps work and suffused other aspects of the project, but the ConOps was a dedicated written space for connecting collaborative goals to agreements about the functioning of the VCC. Further, the ConOps work changed in structure and content over time, allowing a different prism through which to view changing stakeholder beliefs and desires, and how they interfaced with the different

stages of maturity of the VCC project. The ConOps shows attempts not only to provide different tools to support work infrastructure, but to (at some level) reformulate the work itself and the divisions of responsibility for it.

Ingestion of agency dispatch feeds

This subproject consisted of the initial structural work to set up data feeds from the agencies (SFD, SPD, KCM, WSP) with Computer-Aided Dispatch systems, into a single table in the VCC. The Feed was the first time a running list of events from all these agencies was brought into one place for VCC users to view. Work on this subproject was led by the more technical members of the design team, particularly the lead developer from Pariveda. They had several meetings with the IT staff at the agencies who maintained these systems, in order to set up and troubleshoot the integrations. However, all design team members participated in it to some degree.

This subproject was important for my analysis because it is a more technology-focused examination of key existing agency infrastructures, how they're structured, and what basic challenges existed for bringing them into a shared system. Further, it places agency IT personnel more front and center, which is less the case for the other subprojects. Their roles in maintaining and making (il)legible the agency work infrastructures are sprinkled throughout the subprojects, but clearest here. This subproject also gives insight into the creative (as well as obstructive) roles of the IT personnel at the agencies. Interactions with them to set up the data integrations also provided a more granular look at existing work infrastructures and their own rhythms of "longevity/sustainability" and "globalness" for their current users. While I did not focus significantly on interactions with agency IT organizations, understanding it at some level is critical for telling the story of the VCC effectively.

Baseline interface creation

This subproject consisted of the development of the key components of the VCC's interface and the basic logic of connection between them, including the structure and triggers for the VCC's incident model. As this subproject had significant technical components, but also critical process and user interface design aspects, this was the subproject with the broadest participation among the entire

design team.

This subproject is important because it was the largest concrete project of interface development, but also because it largely (though not exclusively!) consisted of the design team's interpretations of the needs of agency stakeholders, and translation of those interpretations and their own preferences into working functionality. In that sense, it most directly allows exploration into the roles of the design and development teams as stakeholders themselves. It also had to grapple to an extent with the existing work infrastructures the stakeholders used: existing systems were the only comparisons we had to prospective VCC functionality. The size and "globalness" of the VCC community's different work infrastructures look different when parts of them are required to scale beyond their original reference points–to an inter-agency operational community. The VCC's novelty can, through analysis of this subproject, also be used as a probe to elicit more information about the embeddedness of existing systems that continue to be used alongside the VCC.

UFRs (Use, Feedback, Refine) 1 and 4:

Use, Feedback, Refine (UFR) was the VCC's version of user acceptance testing, or the granular and structured evaluation of functional system components by users. This was conducted during and slightly after the most active period of interface development. It included extensive structured, concrete assessment of the current working version of the system and perceived collaborative challenges of a wide variety of future VCC users, and in many cases their first exposure to the new VCC.

There were four UFRs conducted during the project, with slightly different techniques and populations each time. Here, I primarily focus on the first and last UFRs (UFRs 1 and 4). The first UFR took place early in baseline interface creation, and included several initial interviews with people who were less familiar with the VCC. The fourth UFR took place in spring 2022 and included both workplace observations–with some incorporation and observation of VCC prototypes in these settings–and structured task elicitations. A very high-level timeline of all four UFRs and their primary activities is given in Figure 4.1.

Many UFR activities provided unique insight into the aspects of the research question focused on how stakeholders collaborate with each other and with the design team. The UFRs allowed me

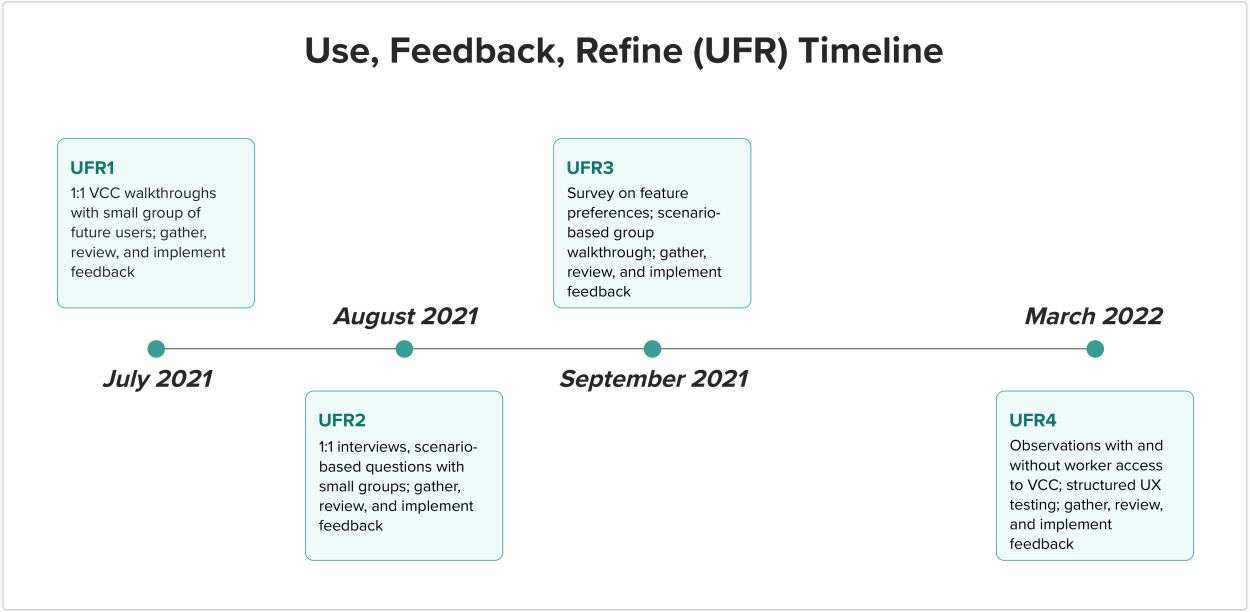

Figure 4.1: Timeline of Use, Feedback, Refine activities

to see some of the interconnections and dependencies of TIM-CM work from the point of view of a new system under development; that is, the embeddedness of existing installed bases could be evaluated with respect to the proposed changes being considered for the VCC. The design team created elicitations to learn about both current ways of working and needs for future functionality as design activities for a new shared system. These design-oriented methodologies brought stakeholders together to envision new forms of shared usage that could be tangibly useful for them.

Full VCC rollout

This is where the VCC became incorporated into people's real daily work. It allowed more tangible and consequential comparison and integration with existing work infrastructures, such as how its portrayal of current traffic conditions compared with users' existing availability to such data. It also opened the possibility of speculating about the collaborative future of the VCC's operational community, such as the emergence of interagency Standard Operating Procedures (SOPs) around shared expectations for how data would be entered into the system. The processes, phenomena, and artifacts Pipek and Wulf associate with work infrastructure development, as well as potential

dynamics like infrastructural grind [74] (for example, the ability to view construction events on a map sourced from a third party service leading to greater interest in including construction events in the VCC) and double infrastructures [66] (for example, the management of traffic cameras as physical devices affecting how reliably they appeared in the VCC's traffic camera snapshots) could most clearly be observed or evaluated here.

Phase 1 evaluation observations and Phase 2 evaluation interviews

These activities provided structured, dedicated opportunities to discuss with people their experiences and beliefs about the VCC so far, and how it touched their current systems and ways of working. It is a good complement to the more opportunistic and serendipitous learnings of the rollout. This subproject is also key for understanding some of the continued "grind," appropriation and design-after-use of the VCC described by Pipek and Wulf [117], and Jabbar and Bjørn [74], and changes in control from some groups (particularly the UW design team) to the end users and to the eventual WSDOT product owners.

Initial Analysis for Corpus Curation

My data corpus, and my own experiences, are very complex, so it was important to refine the corpus in a way that doesn't only avoid eliding that complexity, but finds analytical value in it. After identifying the subprojects I would be focusing on, I created a separate Situational Analysis messy map for each subproject of interest. This exercise helped me select from my corpus individual data items that best help me trace these phenomena of interest, while maintaining general adequate temporal, stakeholder, and topic coverage. As an example of the output of this exercise, the messy map for the ConOps subproject is shown as Figure 4.2. From left to right: concepts and processes are colored green, documents and systems are colored yellow, organizations and teams are colored blue, and individual persons are colored purple.

The creation of these initial messy maps allowed me to see better how very different entities could all exercise influence on their respective subproject and each other. For example, in Figure 4.2, the ConOps subproject's messy map helped me structure many emerging concepts that enabled me to direct my attention toward my corpus more effectively. As an illustration: the concept of

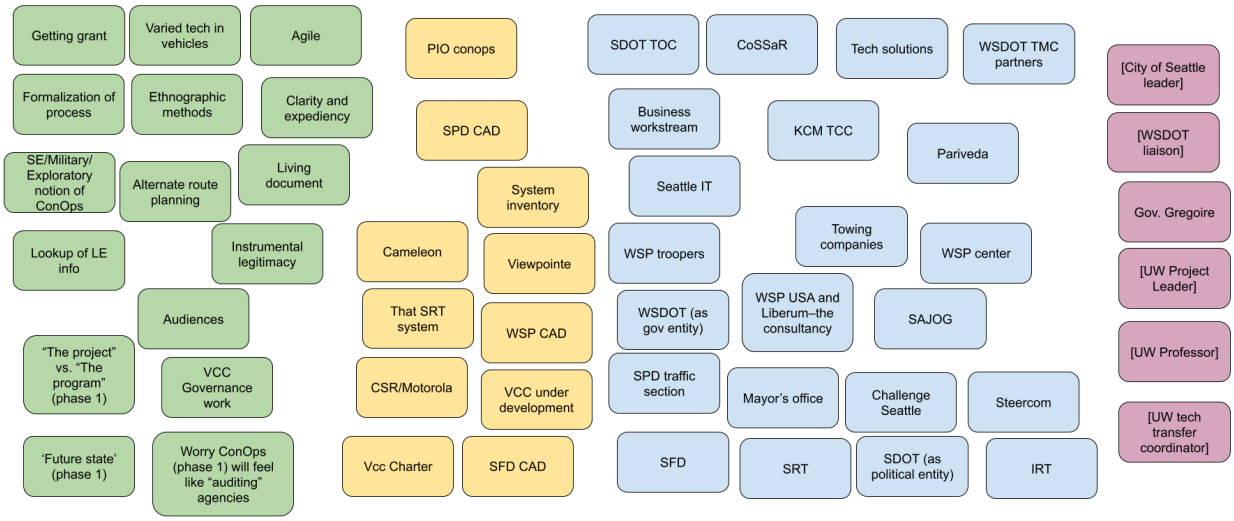

Figure 4.2: Example "messy map" focusing on the Concept of Operations (ConOps) subproject

"ethnographic methods" (which we had to make the case for using) and the notion of being a living document all influenced how the ConOps subproject was conducted, and a desire for clarity and expediency provided the rhetorical basis for advancing some approaches for the document as opposed to others. The document of a system inventory, the organization of the Seattle Mayor's office, and the individual of "The General" (a Seattle city employee who briefly co-led the ConOps subproject) could all exercise influence on the ConOps subproject and each other. Further, each messy map had some overlapping items, and repetition between messy maps was an indication that a particular item might merit special scrutiny or consideration. Conversely, the same item might be quite influential in one "map" but not in another. For example, Agile was a fairly unproblematic methodology used in the Initial Dispatch Feed creation, governing what activities were done at what rhythm; while it was a contentious notion requiring significant socializing and fitting to process for the ConOps subproject. Additionally, laying out these items of ontologically different kind together prompted me to realize that organizations acted both operationally (the kinds of work they did) and politically (how they positioned themselves as political actors) in the ConOps project. This led me to focus greater attention in my analysis on this distinction.

4.3.5 Coding Data and Selecting Themes with Thematic Analysis

Documents for each subproject were uploaded to the web version of Atlas.ti, a popular qualitative data analysis software. In total, within the six selected subprojects, there were 243 documents/artifacts in the primary dataset, each representing some unique slice of data relevant to the research question (the initial corpus included many partly overlapping documents and duplicates). In addition, 30 documents containing notes from VCC Steering Committee meetings were uploaded as additional data–not directly contributing to the analysis, but providing historical context as needed. Once I mapped out the situation to condense my corpus further into a rich but tractable final list of data items, and effectively locate my own positionality within it, I then turned to a modified form of Thematic Analysis (TA). Thematic Analysis is a methodological approach to analyzing and making sense of qualitative data, via a disciplined search for meaningful patterns, categories, and ultimately "themes" in a qualitative dataset [17]. Vaismoradi1, et al. identify a movement to greater abstraction in theme labels as an indication of analytical refinement in Thematic Analysis [156], though themes can take a variety of forms. Because it emphasizes finding patterns across a dataset, rather than within a single data item, it is less suitable for case studies [16]. Its hallmarks are epistemological and theoretical flexibility, leading some to characterize it as a more generally applicable method than a methodology in its own right [16]. For example, it is commonly used to seek out "meaning" or describe "reality," but can accommodate a range of perspectives on how meaning is created or how reality is constructed [16]. However, Braun and Clarke have striven to clarify that TA is not an "anything goes" approach–while it relies significantly on the analyst's own careful reflection rather than a predetermined theoretical position, it simultaneously demands honesty and explicitness [16].

I have selected Thematic Analysis in part because it allows for both inductive and deductive [60] analysis, as this allows me both to discover new ideas from my data, and evaluate and refine well-developed theoretical frameworks. A combination of inductive and deductive analysis is also key for faithfulness to the project itself; the constant interpenetration of research goals and pre-defined instrumental design goals that shaped the research itself means that a pure grounded theory [61] approach would not be possible.

While TA is highly interpretive and driven by the goal and creativity of the researcher, six

typical steps of Thematic Analysis are:

- Stage 1: Carefully read and become familiar with the data. This often means multiple read-throughs and casual, unstructured notes about what might be interesting about the data.

- Stage 2: Create and apply initial codes that may be descriptive, interpretive, or a mixture of both. This is similar to "open coding" in typical grounded theory analysis. In this stage, data can be segmented in any way that makes sense, and this is valuable for me because my data take many forms and structures. When the analyst is coding data, they can use a more "semantic" or "latent" approach–crudely, whether they are identifying what arose in the text itself, or whether "underlying" phenomena are being described [16]. While I borrow considerably from the language used by participants, especially since they are domain experts and I am not, I also recognize that my dataset's considerable heterogeneity (in format, origin, and participants) lends itself more to a latent analysis. I also typically use a more constructivist epistemology, in no small part because the dataset literally tells the story of "constructing" a new design and developing collaborative frameworks.

- Stage 3: Searching for Themes. As Braun and Clarke describe, this is not a pure "search" for something latent in the data, even if one is primarily using latent analysis; but an active "sculpting." A theme "captures something important about the data in relation to the research question, and represents some level of patterned response or meaning within the data set . . . Searching for themes is an active process, meaning we generate or construct themes rather than discovering them" [17]. The analyst reviews the coded data to identify any broad topics or issues the codes cluster around, beginning the process of organizing and mapping them into a possible overall story of the data, so that they "reflect and describe a coherent and meaningful pattern in the data." A theme doesn't have to be any particular "size"–a theme is not chosen because it is the most prevalent candidate theme, though it is expected to recur to some extent (else it could not be a "pattern") [16].

- Stage 4: Reviewing potential themes. Here is where the theme "quality checking" happens. Especially important for large datasets where it's hard to keep everything in one's mind, this

phase involves "a recursive process whereby the developing themes are reviewed in relation to the coded data and entire data set." The analyst checks the themes against the data extracts and decides whether each theme works in relation to the data. If not, this might require removing or rearranging codes. Here is where being faithful to the data is key, and keeps the deductive researcher honest. The analyst has to ask several questions for this "quality checking" phase–such as whether something is truly a theme or just a code, what the theme includes and excludes, and whether there are enough meaningful and coherent data to support it.

- Stage 5: Defining and naming themes. This is the final stage of analytical refinement, where themes are given their complete definitions and final names. This is not meant to be a rote or facile exercise; themes should have a singular focus, don't excessively overlap, and directly address the research question. Here is where the deep analysis happens and the narrative is refined. The collected data extracts help to structure the analysis, but the analyst needs to go beyond simply quoting them; they are the basis of analytical material, not the end point of it.

- Stage 6: Writing the report. For me, this takes the form of writing dissertation materials, and perhaps papers.

During Stages 3 through 5 I complemented my analytical process with aspects of Gerson's "discovery approach" [59]. This involved identifying, in a lightweight fashion, a few categories within the data (not only unordered themes). This type of coding proceeds "by treating each observation as exemplifying some value of some variable, or some attribute of some property. Specifying what attribute of which property is the critical coding step." Cross-classification of data categories in a tabular fashion helped me figure out where the gaps are, which helped to structure my ongoing investigation.

For example, when I assessed the candidate code *Fear of creating low-quality information*, which was classified under the category "Designers and operational stakeholder mediating the social/human capital/political realities with VCC structures," it was originally organized in terms of individual people's concerns about being an accurate collaborator in the shared work managed

through the VCC. However, when I considered it in tandem with other codes in its category (including final codes *Different types of workers and trust models* and *Protecting workers from demands of VCC*), I restructured much of the code's content to focus on how *agencies* managed and controlled their individual workers' contributions to the VCC. Data quality was still an important attribute, but I refocused it in terms of how organizations take responsibility for their members' participation in shared system use.

Coding Final Dataset

My first round of analysis consisted in an unstructured read-through of all 243 primary documents. I conducted this read-through in an analytically open, grounded fashion initially, while writing the literature review, allowing the overall shape and impression of the dataset (e.g., relations between concepts or actors, what kinds of information or impressions were captured in which kinds of documents, where gaps were obvious and where there was great detail, who was producing what kinds of data points), to inform how I attended to concepts in the literature, and vice versa. Potential passages or items of interest within the documents were marked with the Atlas.ti "quote" function. A total of 1838 quotations were marked. I added initial open-ended comments to the vast majority of these quotations. Some of these comments were descriptive, and some were analytical, cross-referencing to relevant concepts in the literature, as appropriate.

After creating this database of quotations/selected passages, I developed initial analytical memos. Each memo was intended to capture some ideas of interest that arose from the data. These memos were a combination of descriptive (e.g., "Reasons for hesitations to use VCC"), analytical (e.g., "Inter-organizational work infrastructure is a forest"), and theory-testing (e.g., "Local articulation and metawork to help VCC work go well").

After reading through these memos, I used the titles and descriptions of each memo to create an affinity diagram that led to initial possible themes and codes. I then iteratively recoded the code database in three phases. The first phase included open-coding in the part-deductive, part-inductive approach advised by Thematic Analysis. The second phase was creating an early codebook, synthesizing the codes into early groupings. I then re-analyzed those quotations (149) for which an existing code did not initially fit. This led to a long codebook of 71 codes, not struc-

tured into themes. After iteratively analyzing this codebook and incorporating the analysis of my interviews (described below), I chose an analytical "slice" of five themes, with four to six codes under each theme, for the thematic analysis. I undertook a final structural analysis of the themes, resulting in nine primary final themes. The final codebook is presented in Appendix B. When data excerpts are presented in this dissertation, organizations are usually given by their actual name, but all human names except my own are pseudonyms.

4.3.6 2025 Interviews

After conducting initial analysis on my selected sub-corpus and producing themes and further questions, I conducted a round of focused semi-structured interviews with project stakeholders and performed a second round of analysis on the resulting interview data. I sought not only to learn facts about the VCC's usage, but bring participants on "as meaning makers, not passive conduits for retrieving information from an existing vessel of answers" [159], where their and my perspectives over past events and possibilities for the future interacted. My initial data corpus, as it was entirely a historical corpus from the VCC project ending a few months after full operational deployment, did not fully help me analyze the more gradual changes the VCC might be expected to connect to post deployment. Further, it is difficult for either operational stakeholders or designers to have full insight into the meanings of their experiences in the moment; some period of remove and reflection can help them reflect more completely.

In my participant recruitment approach, I strove to achieve a good balance of project roles and experience with the VCC. For the "design" stakeholders (that is, those who worked on the design team in some capacity, either at the Pariveda software design company who did contracted VCC software development or UW), I used my previous personal connections to reach out to individuals I thought represented a strong range of characteristics. For the operational stakeholders, I reached out to people in my personal network from my project experiences, but I also used a small amount of "snowball sampling" [114] to connect with people who had either started working at their agency after the VCC was deployed (and thus whom I wouldn't know personally) or whom I had less strong personal connections to before, but who might have valuable contributions. Interviewees were not compensated for their participation.

My final interviewee roster consisted of thirteen operational stakeholders and four design team stakeholders. Information about participants is given in Table 4.1. Affiliations included University of Washington, Pariveda, King County Metro (KCM), Seattle Police Department (SPD), Sound Transit, Seattle Department of Transportation's Transportation Operations Center (SDOT TOC), Washington State Department of Transportation (WSDOT, including office staff, Transportation Management Center (TMC) staff, and Incident Response Team (IRT) staff), and Washington State Patrol (WSP). Interviews were conducted between March 5 and April 4, 2025, and lasted between 45 and 70 minutes. Except for one interview that suffered technical disruptions, all interviews were recorded over Zoom or Microsoft Teams, and I manually cleaned each autogenerated transcript.

I created interview protocols based on themes identified in my analysis of existing materials, with a key goal of learning about the changes in VCC use over time–after an extended period of daily use (or for some, multiple years of infrequent or non-use). The interviews asked both categories of interviewees about their history of exposure to the VCC project, and how their understanding of its goals changed through their exposure to it. Design team stakeholders were asked about the kinds of work they did on the VCC, their perceptions of various methodological approaches the design team took in the project, and what they personally learned about managing a design project of this type from participating in the VCC. Operational stakeholders were asked about what kinds of incident work they do, how their usage of the VCC has changed, how the VCC has become incorporated into their work and their collaborations with others, and what they currently like and don't like about the VCC. Interview protocols are provided as Appendix A.

The final section of the interviews with operational stakeholders further included a walkthrough of a fictional major incident (while fictional, its characteristics drew upon prior major incidents for the sake of verisimilitude). One of the thirteen operational stakeholders, a police officer, was not given this section of the interview because of time limitations. From gathering their responses about how they would learn about, act on, and analyze a hypothetical major incident, I was able to "crowdsource" an extended major incident narrative, which will be shared in the next chapter. This part of the interview not only helped me gather details that will more effectively orient the reader to the context, stakes, and types of work VCC operational community members do, but will also foreshadow some of the key themes I discuss in chapters 6-8. Importantly, it was also intended to call back to the work done during the VCC project itself, of working with operational

ID	Affiliation	Incident or Project Role	VCC Project History
P1	KCM	Public Information	Began participating from early in the design process
P2	KCM	Transportation Management, Leadership	Began participating before design (early SAJOG meetings)
P3	Pariveda	Design	Participating from pre-design phase
P4	Pariveda	Design	Joined mid-project
P5	SDOT TOC	Congestion/Traffic Management	Learned of VCC mid-project, offered stakeholder input
P6	Sound Transit	Transportation Management, Leadership	Joined Sound Transit mid-project, offered stakeholder input starting shortly thereafter
P7	SPD	Incident Response	Began participating from early in the design process
P8	SPD	Incident Response, Leadership	Began participating from early in the design process
P9	UW	Design	Joined project partway through design process, left shortly before full operational deployment
P10	UW	Design	Began participating before design (early SAJOG meetings)
P11	WSDOT IRT	Incident Response	Learned of VCC mid-project, offered stakeholder input
P12	WSDOT IRT	Incident Response	VCC was already fully deployed when they started working at IRT
P13	WSDOT TMC	Congestion/Traffic Management	Began participating from early in the design process
P14	WSDOT TMC	Congestion/Traffic Management, Leadership	Began participating from early in the design process (early SAJOG meetings)
P15	WSDOT	Public Information	Joined WSDOT mid-project, offered stakeholder input starting shortly thereafter
P16	WSP	Incident Response	Learned of VCC mid-project, offered stakeholder input
P17	WSP	Incident Response, Leadership	Began participating before design (early SAJOG meetings)

Table 4.1: Interviewees

stakeholders to craft "operational scenarios" that were used in both governance documents (such as the ConOps) and to frame codesign activities and workshops. As such, this was a conscious blending of standard qualitative interviewing and specific callouts to the familiar design processes of the project.

4.4 Summary

In this chapter, I have sought to present the nitty-gritty of how the VCC project's data were generated, and discussed it in terms of a few different methodological approaches that can be applied to similar projects. I then described how I used Situational Analysis and Thematic Analysis to curate and organize this corpus, gather more data in the form of qualitative interviews with a wide range of project stakeholders, and iteratively develop the themes that drive the analysis I present in following chapters.

Chapter 5

EXAMPLE MAJOR INCIDENT SCENARIO COLLABORATIVELY DEVELOPED WITH INTERVIEWEES

5.1 Introduction

As described in the Methods chapter, one section of my 2025 interviews with operational stakeholders was walking with them through a hypothetical major incident scenario. This chapter represents the synthesis of their responses. It is meant to serve a few purposes in the context of the dissertation. First, it will illustrate realistically and vividly the complexity and stakes of a major traffic incident for the Seattle TIM-CM community, bringing together the ontological richness of a major incident, the shifting collaborative and information-seeking tactics those working in it employ, and the layered materiality of this challenging sociomaterial object of study (both pre- and post-VCC). It will also establish context for the analytical chapters, where I make several references back to this narrative for illustrative and comparative purposes.

Finally, this narrative provides in a richer and more extended format the kind of "operational scenario" whose development and use were so important in the VCC project. This incident scenario is meant to be a demonstration of the *accomplishment* of the methods the operational stakeholders and design team used in the project, as it brings together so many different analytical lenses and lived experiences of this domain. That I was able to synthesize these viewpoints is not to be seen as purely the outcome of a method I used, but as an *outgrowth* of the years of work we have all done.

The chapter is structured as follows. First, I give the context of the fictional incident and its triggering event. I then synthesize how interviewees 1) detect the incident, 2) incorporate vCC information (and when) into their understanding, 3) work the incident from the perspective of their own role, 4) collaborate with others within and across agencies and make sense of the incident's impacts on other agencies, and 5) recover from the incident and analyze it after closure. I then provide some closing thoughts about what this incident reveals about traffic incident management

in the Seattle area, and set the stage for my analysis chapters.

5.2 Narrative

It is about 4pm on a cold Thursday. It's raining lightly and might start raining harder, or maybe even snow. Near the Seattle Convention Center on I5 northbound, a large commercial vehicle loses control and starts to jackknife across the freeway. It crashes, striking multiple additional vehicles and releasing an initially unknown substance, blocking all northbound lanes except part of the right lane (in traffic management parlance, this is "lane 1"). This one intense moment kicks off a multi-hours-long major incident that will call on the efforts of a wide range of actors in the Seattle area Traffic Incident Management-Congestion Management (TIM-CM) community.

Various factors make this incident complex and challenging, even from its inception. The weather conditions reduce friction on the road and visibility for drivers. Thursday afternoon is commonly the most congested day and time of week. Further, this particular location is always difficult to manage, with its proximity to high-traffic areas like the Convention Center, complex arrangement of exits and diversions, and interweaving of upper bridges and underpasses. During this particular incident, there is also a moderately large event happening at the Convention Center, which means that there can be sudden surges of people exiting the facility, and many of those people are not from the area and may be unfamiliar with navigating it.

5.2.1 Incident Detection

When this takes place, the VCC's operational stakeholders are typically engaged in many other tasks, often unrelated to incident management. Therefore, how the incident is detected and to what extent stakeholders need to "task switch" to attending to the incident is critical. They learn about this new and potentially significant situation in a variety of ways, each of which can set the context for how they will make sense of the situation, and begin to allocate attention and resources to it.

The Washington State Department of Transportation (WSDOT) has over 2000 traffic cameras and, taken together, they have adequate visibility into the most visible and large-scale aspects of this incident. However, the flow operators at the WSDOT Transportation Management Center (TMC) have many cameras to attend to, and there are always some feeds that aren't actively being watched. Their "big board" (main camera that takes up the most space on their massive

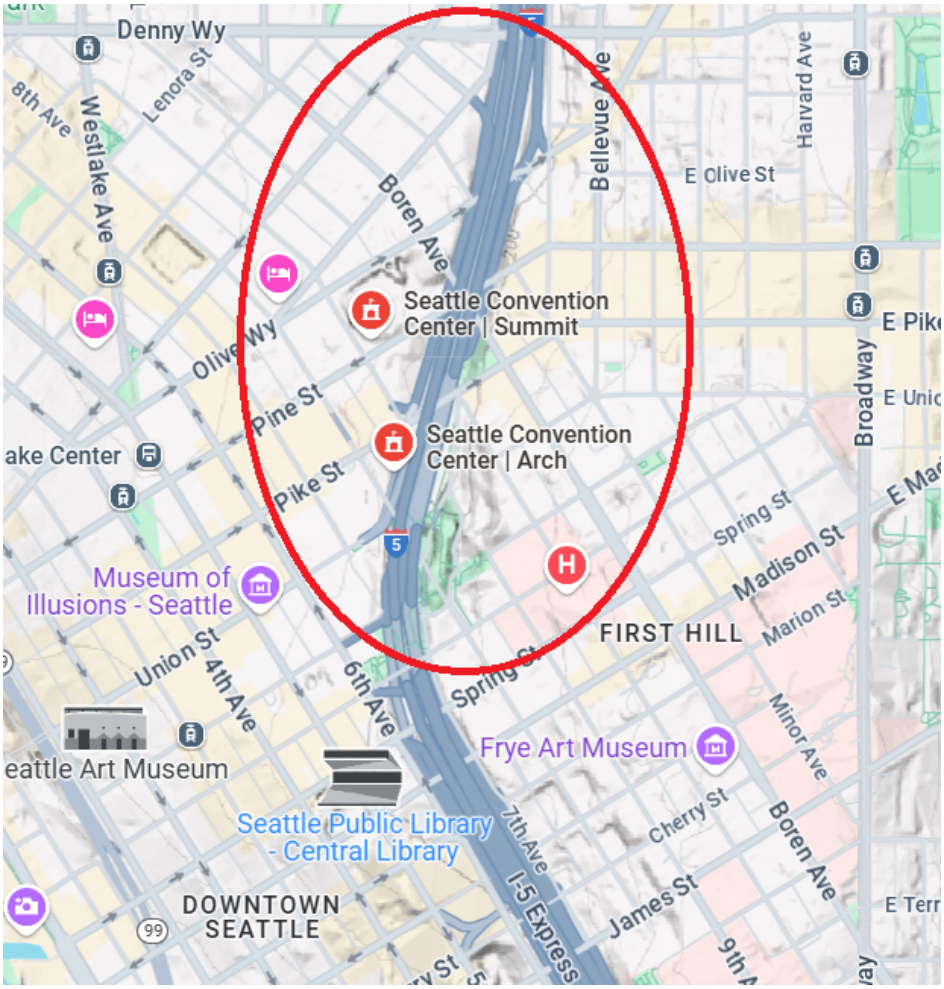

Figure 5.1: Approximate area where the fictional crash happened [from screenshot taken 4/18/2025 on Google Maps]

configurable camera wall) happens to be watching congestion on State Road 522, northeast of Seattle, at the moment when this incident begins. If the flow operators had happened to be watching the camera feeds closest to this incident, they would have been the first to notice it. In this case, the first operational partner to learn about the incident is the Washington State Patrol (WSP), from the first of many 911 calls that come into their Communications Center in Bellevue. Which 911 center a call is initially routed to depends on the physical location from which the call comes, and whose jurisdiction is closest to that imputed location. Because I5 is under state jurisdiction, the calls typically reach WSP first, rather than Seattle agencies like the Seattle Police Department.

Drivers for the WSDOT Incident Response Team (IRT) most likely hear about the incident on the radio. If that isn't the case, they may happen to notice it first from a camera feed from the WSDOT TMC "big board" if the view is pivoted from SR522 quickly enough. This is because they have recently begun piloting a view-only camera feed program from WSDOT. The SDOT TOC's operators, the city's counterparts to WSDOT's flow operators, might also find out about the incident from its own access to the TMC's "big board," or from signals from WSP or Seattle Fire Department. Since various entities are, in a sense, "customers" of WSDOT's camera data, their own path to finding about the incident can be affected by WSDOT's use of this information source.

How people find out about this incident varies not only based on agency and operational community, but rank as well. People in leadership positions often hear about incidents from staff briefings, rather than perceiving them directly. However, this is very contingent–for example, police leaders may also hear about the incident on the radio, particularly if they are out driving when it takes place, or from a "command broadcast" (automatically generated text and phone call) sent to their office. However, quite often, there is often some human filtering from lower-level staff before leaders learn of emerging situations.

People at agencies whose core work is less directly connected to traffic management, such as KC Metro, may hear about the incident via a call from WSDOT partners, from viewing public data feeds from other agencies (such as the Seattle Fire Department's public dispatch page), or other sources such as social media. In the case of KC Metro, those working at the downtown Transportation Control Center may actually learn about the incident from an indirect signal: the

sound of fire engines turning on their sirens and leaving the nearby SFD special response unit. This facility happens to be only a few hundred feet from the TCC, so this can be an early warning signal to them.

A few people might find out about the incident from the VCC itself. The VCC's email notifications, sent when a new incident is created, might be the first indicator for some partners, such as one of my KCM interviewees. Of course, this has to do with how closely they happen to be watching their email, and how well configured those notifications are (some have, for example, set up audible email alerts for VCC notifications). But the VCC is not the sole or primary source of breaking incident information for most interviewees; there is always at least some other equally favored channel. Personnel who occasionally or frequently work from home, and don't have as much access to data sources or multiple monitors, might hear about the situation from a work Teams chat rather than from direct personal observation. Those who are particularly attuned to social media, like public information officers and some traffic control center operators, may also first hear about the incident from social media posts by the public.

5.2.2 When Information from the VCC Enters Their Awareness

The VCC has become an overall important part of incident detection, response, and analysis, but how and when it affects each person or operational subcommunity varies considerably. In this hypothetical incident, the initial VCC incident was created by a WSDOT flow operator, a few minutes after the first WSP CAD record arrived in the VCC's main Dispatch Feed. For IRT personnel, while the WSP 911 dispatch is still the primary and initial way they learn of incidents, if a VCC user is particularly quick to create an incident, or the IRT person happens to be monitoring it, the VCC's information may follow closely behind.

For others, such as public information officers (PIOs) in WSDOT, information from the VCC might lag a bit behind other primary sources; they might receive information about VCC activities from a Teams chat, after a TMC flow operator has created an incident. Others may first notice VCC activity from an email notification, as mentioned above, which they may notice sooner or later depending on how carefully they are watching their email and how plugged in they are into more immediate sources. Yet others are more operationally separated from the VCC, either because

of their job role (executives receiving briefings, as described above), or perceived disconnection from the VCC's operational community (some at Sound Transit, for example, might not see VCC information at all in most incidents).

Some operational partners may only find out about the incident from later, public sources like news broadcasts, if at all–their specific focus on their stations and facilities means they often learn about major incidents late. For agencies that have not fully adopted the VCC into everyday work, the VCC is a peripheral tool for even their most involved users, so the VCC's email notifications about the incident may or may not filter into their awareness. It's entirely possible that they only learn about the incident because security personnel at nearby stations notice an unusual influx of people, or overhear chatter about the incident.

In any case, when the various members of the TIM-CM community learn of the incident, most of them consider it significant enough to begin, at a minimum, monitoring and analyzing it, even if they don't have specific tasks to do at the outset.

5.2.3 Handling the Incident

Now that people are aware of the incident, they can begin taking action. Location is one of the most important data points for incident management, and is likely to be one of the first things people want to ascertain. Those working close to the scene–either physically or operationally–will attend to fairly subtle nuances in exactly where the incident is taking place. For example, IRT personnel might identify how far the incident is from the collector-distributor lane or other exits, and whether the express lanes (which can be changed in direction by WSDOT based on traffic patterns) are flowing northbound or southbound. These changing characteristics can drastically affect how feasible it is to divert traffic away from the incident and at what distance from the crash, and what kinds of impacts that diverted traffic will have on city arterials and smaller roadways (which can then, of course, create other transportation issues in other locations). On-scene incident managers work to determine whether it is possible to allow some traffic to trickle through on particular lanes, based on the ambiguous hazardous materials (hazmat) situation. The impacts of potential hazmat can rapidly change the situation, depending on whether it is liquid rolling downhill, aerosolized in the wind, or if it can be quickly determined to be harmless based on speaking with Commercial Vehicle

Enforcement (a Seattle unit that liaises with companies to ensure their commercial vehicles comply with laws and regulations).

Location can also affect who the relevant stakeholders are in an incident. There are the typical operational partners–WSP, IRT, WSDOT, SDOT, and SFD–but there are also likely impacts to nearby facilities, such as the Harborview Hospital. This medical center is physically close to the scene of the incident, so it could become inundated with patients quickly. Every such calculation can have an impact on the complexity, danger, and duration of the incident. As one KCM interviewee commented, this is a "geometry problem" where the highly constrained bottleneck of Seattle and its road networks shape movement in three dimensions, into, out of, and within the busy downtown core and neighboring towns. People working on scene, and those assisting them, also use their expertise on the structures and infrastructures of the nearby area to problem-solve about how to best physically manage the situation. Unique characteristics of the area offer opportunities for different mitigation and safety tactics. For example, a WSP interviewee reasoned that "since [the traffic is] going northbound, probably somewhere up near the [state highway] 520 where we could get a casualty collection point, have people pull over to the side and have EMS respond to that area to treat them."

For some in monitoring and coordination roles, like managers at the WSDOT TMC, the first order of business will be to determine who needs to be messaged to, or might have relevant information, both within and outside their own agency. For example, because there's potential hazmat, the Fire Department would be an early contact since they would be the initial lead/command on that aspect of the situation. Allowing this information to flow properly can allow those arriving on scene to approach more safely and strategically.

Meanwhile, SDOT TOC personnel are monitoring the situation. While they are not actively intervening yet, they are already thinking about which main city arterials are most likely to be affected, and preparing to activate DMS (Direct Message Signs; the overhead highway signs that can alert drivers to changing conditions, Amber alerts, updated speed limits, etc.) near these arterials to divert traffic in the most effective way. This monitoring and analysis changes as the situation changes. The TOC is in frequent communication with the SDOT Response Team (SRT, the City equivalent of IRT), both over phone and MS Teams chat. They are also reaching out to Commercial Vehicle Enforcement with the partial details currently emerging about the owner,

route, and contents of the commercial vehicle.

In the case of this incident, the first WSP trooper on scene–who was patrolling nearby and so was able to arrive quickly–takes initial incident command. Two IRT units, hearing about the incident and checking the VCC and the camera feeds, volunteer to join the effort. Seven Seattle Fire Department units also hasten to the scene. The ranking firefighter, seeing the injuries and potential for hazardous materials, temporarily takes over incident command from the state trooper. The initial assessment is that there are 10 injuries including the commercial vehicle driver, at least two of which are very serious and will need immediate transport. One of the seven fire units, which is an aid unit, quickly removes them to Harborview hospital nearby. Three cars are totaled, and two more damaged but able to be moved to the side of the road.

By 5:30pm, a WSP lieutenant arrives and takes a more formal incident command. Normal peak traffic, and logistical issues relating to this incident, made it impossible for him to arrive much sooner. The lieutenant quickly begins directing the trooper and IRT personnel on where to establish a safety perimeter and investigation perimeter, and to set up the IRT driver's truck into signaling mode, which more effectively closes all northbound lanes and (for safety) one southbound lane. This helps the SFD personnel begin assessing for hazmat.

An incident command post is established north of the northmost involved vehicle, a few hundred yards south of the casualty collection site. This changes the flow of personnel and information. Now, other personnel arriving on scene would check in at the incident command, syncing up on relevant information and taking orders. People actively working at the incident might now learn about changes in the situation from the command post, and people leading work on the incident might be receiving information from external sources (such as radio) that they can then convey to others working on scene. If someone working on scene has the time, equipment, and access, they might be able to get updated information from the VCC, as others contribute incident information. However, most people working on scene cannot persistently pay attention to the VCC, and even less often do they have the time to actively enter such information. Rather, it is more typical for on-scene workers (such as IRT personnel) to convey information to colleagues in stable facilities like the TMC, and those personnel then enter information on their behalf. Public information personnel get their information from a variety of sources, including social media, their agency colleagues, their public information colleagues at other agencies, and more; and the lead PIO may join the scene at

a certain point.

While stakeholders are taking action, they are also beginning to make predictions that will drive their future actions. When projecting likely impacts, some partners start with the likely "worst case scenario" and then gradually work backward/reduce urgency as more is learned. For example, one KCM interviewee uses the potential worst case scenario (extended unavailability of a major thoroughfare with a large operational perimeter, at rush hour–a disaster for the bus network) as a starting point for decision-making. Doing this lets him start planning the complex, highly interconnected work of rerouting buses and even pausing certain routes. To change the operation of a bus route can require any of the following, depending on the situation: asking current drivers of the route to pull off the road; calling in additional coaches from one of the nearby bases; re-allocating currently working drivers to new routes; contacting on-call drivers to patch in and take a new route; directing field supervisors (non-driver staff who can assist drivers on the road with various issues) to identify and test out a temporary reroute, which the communications center must then send over to the pertinent drivers both verbally and with a transmission to the pertinent bus's onboard system via a radio signal; and communicating to the public and agency partners about the reroute. As these changes happen, there can be cascading effects on the road network, as passengers "bunch" at stops, attempt to switch modes (perhaps to the already quite busy light rail network, or worse yet, private vehicles), and clog up small side streets that aren't built for the kind of capacity that's being demanded of them. Most of the time, these negative consequences are minor and fleeting, but the potential for such problems is always present. Because, in this incident, the weather is cold and damp, and several routes are disrupted anyway, KCM coordinates with SFD to direct an empty coach to approach the scene and serve as a warming shelter for victims and witnesses.

Many VCC operational community members frame their participation in terms of serving other members of the operational community, as much as resolving the incident itself. Working on behalf of others who will be vulnerable to the incident's on-scene conditions, a WSDOT manager will first evaluate the safety conditions for the people being dispatched who have a direct organizational connection to them. In this case, they check conditions on behalf of IRT. This initial evaluation will be intentionally conservative and cautious, because protecting the crew's safety is paramount. Lack of useful information early in an incident can be a literal occupational hazard, especially for on-scene

personnel. For example, police officers who rush into an ambiguously dangerous situation and suffer the consequences before the dangers are understood are sometimes called "blue canaries." In this case, if the hazmat situation is not yet known, but an officer or firefighter heroically enters the scene to take life-saving action, that officer or firefighter may be contaminated with hazardous materials and suffer health problems later. This is but one example of the importance of gaining high-quality information quickly, and disseminating it effectively. However, using this general approach will impact the total duration of the incident because preparing for greater safety can take more time, space, personnel, and equipment; and any personnel or equipment who are not already on scene will take time to arrive, especially given the traffic conditions.

For this incident, it's particularly obvious just how much downtown city conditions (where the City has primary jurisdiction) are interdependent with incident conditions. Due to assessments by the TOC in communication with Seattle traffic engineers, signal timing on arterials near the incident is being tweaked, and the TOC and TMC are using this adjustment to the flow of traffic to further strategize the placement of direct message signs on both the freeway and relevant city streets.

As the situation evolves, there is a wide variety of signals people are watching for, and contributing to on behalf of others. Not all parties are attentive to the same signals; together, these varied sources and varied assessments of them create a rich and complex picture of the same "incident." These signals come from heterogeneous sources–some highly vetted and trusted, some more chaotic and serendipitous. Any visible or informational changes in the hazmat situation would of course lead to different mitigation actions, such as establishing a medical aid area, changing the safety perimeter, or bringing in subject matter experts or specialized equipment. Evidence of criminal culpability would change how the state patrol interacted with the situation, potentially creating an investigation perimeter that is different from the safety perimeter. More dramatic behavioral changes in drivers near the scene–rapidly abandoning vehicles, for example–can also occur. This prospect was described by one interviewee as the situation "spiraling."

The Commercial Vehicle Enforcement (CVE) representative who's consulted on this incident says the substance isn't immediately poisonous. However, the large quantities of it, and possibility of runoff, might necessitate caution, and agrees that the state Department of Ecology needs to come to the scene. The initial investigation, conducted by WSP with consultation from CVE,

is inconclusive. The driver is injured but coherent enough to be lightly questioned before being transported to the hospital, and he says that there was a mechanical issue exacerbated by the weather conditions. He is assessed for inebriation and determined not to be obviously under the influence of any controlled substances (though the concussion he sustained made this slightly less clear, behaviorally). Incident command reaches the decision that further forensics would need to be conducted on the commercial vehicle, so a tow with sufficient capacity is contacted and brought to the scene, which takes about half an hour even though the facility where it's staged is only a short distance away. A representative of the Department of Ecology is there by around 7:30pm to assess the scene, and works with SFD to make recommendations about mitigation, and with WSDOT to plan cleanup and barrier repair efforts.

Because there are several casualties and significant damage and debris on the roadway, the incident command radios WSP to request additional IRT personnel to join the scene. IRT drivers approaching will not only be using radio communication to plan their approach, but will also be checking environmental indicators like real-time weather reports, because weather changes can have such a substantial change on the incident conditions (slippery road, hazmat runoff, etc.), and what resources might be useful to bring. If able to safely, they may also watch traffic flows on the WSDOT camera feeds, particularly within one or two exits of the situation to "know what they're getting into." One further IRT unit heads toward the incident; but because the SRT overhears some of this chatter, their dispatcher inquires whether any SRT can offer assistance as well, and one nearby SRT unit self-dispatches to join the effort. The context they already have lets them know to have personal protective equipment (PPE) on the ready.

Participants in this incident are attending to their own systems and tasks. However, importantly, they are also attending to the work and operations of other agencies, and making inferences from that observation. These are updates coming from other agencies or other sources beyond their own specific tools and jurisdictions. What is a primary signal for one participant may be a secondary signal for another, and they may have different knowledge and context about those signals. A KCM PIO, for example, watches for estimated cleanup times from responsible agencies like WSDOT or SDOT, and uses those to help adjust KCM's transportation and communication strategy. Meanwhile, an SDOT interviewee is watching for changes that allow them to better predict durations of closures and detours, which flows both to external audiences like KCM and to internal

audiences like signal engineers. These are general principles, however–for this specific incident, the possibility of hazmat is a factor that can make the situation far worse, and create a larger safety boundary that has to be managed.

5.2.4 Shared Situational Awareness Evolving During the Incident

Shared situational awareness, particularly that which transcends physical locations or organizational boundaries as must happen in the management of a major traffic incident, is a fickle thing requiring frequent tending. Information that was canonical five minutes ago could be misleading now; responsible people change hands as tasks change and people rotate off their shifts; estimates and predictions get strengthened or discarded; and downstream mitigation actions (such as changing traffic signal timing) have upstream impacts on driver behavior. How do incident stakeholders manage this?

People learn about changes to the incident in a wide variety of ways and at different times, often highly contingent on which of their many information sources they are most attuned to at the time. A WSDOT TMC manager learns about changes to the incident visually via camera feeds they have access to, a phone call from a partner, or overhearing radio traffic coming from the scene. It may happen that the person being contacted is busy handling the incident, or otherwise occupied (always a hazard of 1:1 communication during an incident). If the person being contacted doesn't respond after one or two attempts, this manager will rapidly seek a different source for the information, because information is needed quickly. As such, it's helpful to have a deep bench of potential resources for learning similar information. An SDOT interviewee at the TOC exhibited a similar typical pattern: they might find out about the incident from camera feeds, SRT on scene, or indirectly from the incident commander (and only then if an SDOT person is more involved in command).

Comparably, if the KCM TCC has been involved in incident command–which would happen under specific and fairly unusual circumstances–KCM leadership might get new incident information from their own participants in the incident command structure. However, given the specific circumstances of this incident, where no bus was significantly and directly involved, they receive information from their agency partners and KCM subordinates attending more directly to the

incident.

Like many other stakeholders, a WSDOT PIO interviewee has pre-existing personal connections to people outside their own agency who they can backchannel to if they intuit that information isn't flowing properly, or simply if they have questions they can't easily get answers to other ways. These long-term personal networks that cross between both agencies and operational communities form an important component of getting incident work done. This human infrastructure [117] of informal coordination [25] can cross organizational boundaries over time, and contributes to creating a larger operational community/multiorganization. However, this often happens in a somewhat covert way, as it typically represents minor, benign violations of standard operating procedure.

Most people whose work connects to the VCC have multiple streams of information across multiple modes coming at them. Leaders are often briefed about conditions from subordinates rather than actively monitoring primary information sources themselves. One law enforcement interviewee pointed out that how he finds out about potentially major incidents depends on the specific circumstances of his work. If he is already on scene, he would learn from his own senses or from another first responder leader (such as an SFD chief). His expertise can also make the on-scene context more informative for him than it might be for others. For example, commercial vehicles are typically required to carry placards that contain information about what's being carried. The ability to notice and interpret that placard can give the incident command a major head start on identifying and mitigating the potentially hazardous substance.

How people obtain situational awareness is not purely a rational, detached cognitive process. A public information officer at WSDOT who manages others encourages them to "practice the pause": balancing quick and effective action with measured, appropriate verification of evolving information. These emerging situations can be stressful, and emotions color everyone's actions. Practicing the pause is a way of acknowledging these emotions while learning strategies to handle them appropriately.

5.2.5 How Participants Think the Incident Affects Other Stakeholders

Even though the VCC's operational community are acting collaboratively and share a distal goal of resolving the incident safely and quickly, partners have their own constraints and goals as well,

which also demand their time and attention. For the Washington State Patrol, investigation procedures will start immediately, though of course many major incidents do not have a criminal investigation component. But using available information to determine whether the incident was likely purposeful, neglectful, or unavoidable, and how severe any injuries or damages were, shapes how they engage with the incident. Beginning to "investigate" right away, even if there is no criminal culpability, is a part of their modus operandi. If the incident had been found to be a potential terrorism event, the WSP would have called in the FBI for assistance (and possibly transferred the incident command to them).

Operational stakeholder interviewees offered a wide range of views on how an incident like this might affect others in the VCC's operational community. Naturally, when asked to name who this incident would affect, the core agencies/groups assumed to have jurisdiction (WSP, WSDOT, and SFD) were named by most. An experienced IRT interviewee predicted that this incident would have a significant impact on SDOT, particularly since there would likely be spillover of traffic onto city streets. This particular location could also be a "hotspot," especially if a large event like Emerald City ComiCon were taking place at the same time.

Other partners who are not usually considered to be core members of the VCC operational community may participate more or less depending on unique characteristics of the situation. For example, the Department of Ecology would be more involved in hazmat analysis and response if the weather conditions contributed to greater contamination (windspeed, runoff, etc.). The significant damage to multiple vehicles also required contacting the towing company the City has a contract with, and preparing for their safe arrival. If the incident had involved a vehicle striking/damaging a light pole or other utilities infrastructure, the relevant utility (such as Seattle City Light) would have to be contacted and join the scene, then activate their own workforce, which might have taken several hours and required different traffic enforcement actions. These examples show just how different major incidents can be, and how flexible yet disciplined the decision-making that goes into them has to be.

Multiple interviewees in non-transit agencies highlighted the potential impact of the incident onto transit: both buses and light rail. Of course, buses would be delayed by the closures associated with this incident, and some core routes might have to be rerouted. As people "peel off" the freeway or avoid it, nearby light rail stations might be inundated with people (which can both cause excessive

loads on the vehicles and make crowd control more challenging for staff on the platforms).

As noted by one interviewee at KCM, all the VCC's participating agencies may well be "maxed out" during the most intense parts of this incident. This makes their ability to respond to other issues they have responsibility for more challenging, and as a result, makes the overall network more fragile. Some interviewees also speculated about potential knockon effects to other jurisdictions. For example, pulling in too many SFD units would activate mutual aid agreements with nearby jurisdictions (such as Shoreline, just to the north of Seattle). These neighboring towns might then temporarily lose the full force of their own fire departments. So, as they explained, someone having a heart attack in Shoreline for completely unrelated reasons could feel the impact of this incident. In this fictional incident's case, that particular network was not taxed in such a fashion, and people experiencing medical emergencies in neighboring towns had much the same experience they usually would. However, because several KCM bus routes were affected and unable to provide their typical service, it was quicker and easier to re-allocate a coach as a warming shelter.

People are considering not only their own informational needs in the incident, but also what operational partners can learn from *them*. This creates potential opportunities for placing some of that information in the VCC, which can free people up to take fewer one on one information inquiries. As one law enforcement interviewee put it,

> Well, I think people that aren't associated with the incident are always craving the information, which is the huge benefit that we get from the VCC. And I'm going to use things like Sound Transit. Their ability to look at that and see what's going on, as long as they have an understanding of what a hazardous materials incident may or may not entail, they can start formulating workarounds without us even having to consider them in the command post like they'll know. OK, well, they can look at the map and they can see what the wind direction is. and if anybody over there has some basic understanding of hazardous materials incident response, they'll say, hey, let's start diverting bus lines. Let's cancel this line. Let's cancel this line.

Another example of this kind of empathy for those in other roles came from another law enforcement interviewee. They noted that there is a considerable burden on the creators of messages (such as PIOs) to get things right, and to anticipate the consequences of others taking inappropri-

ate actions based on their interpretation of information. This includes, of course, drivers on the road misinterpreting instructions and making traffic worse, but also includes the nerve-wracking possibility of executives and politicians running too quickly with a message, and publicly taking counterproductive or reputationally damaging actions like committing to a specific opening time or promising a disciplinary review.

This incident, no matter how unique and singular it is, always happens in the ongoing trajectory of other work. The impacts will be different if participants have to start preparing for longer-term incident work. This activates different resources and different decisions, such as adjusting overtime schedules for workers. In this case, while partners are tentatively able to get traffic moving again later that night, they will need to set aside a few hours for initial cleaning, and to take a lane in each direction early the next morning to assess the need for further cleanup, runoff, etc. As people go off shift, they must take extra care to sync up with the person they are handing operations off to, and the longer the work goes on, the more of these handoffs must take place, which means at least a little information is likely to be lost. However, everyone is fairly aware of this hazard, and takes the time to ensure everyone knows enough to continue working effectively.

As these observations indicate, what people believe about other stakeholders' needs or experiences, or what would impact them, is a common aspect of their own work and planning; this kind of "theory of mind" about other agencies and workgroups, factors into their processes and their situational awareness. Empathy and imagination, as well as experience and knowledge, contribute to successful management of such a complex incident.

In the case of this particular incident, the investigation perimeter is closed at about 8pm, and the final traffic control devices are removed and debris cleaned up at 9:45pm. The night time road workers are brought in to finish initial cleanup. They're gone by about midnight. The TMC closes the VCC incident at this point, now that there are no more blockages. However, a new VCC incident model is created for the longer term closure the following day, to analyze the runoff and repair damage to the barrier.

5.2.6 Analysis and Reporting After Incident Closure

The life of a major incident is far from over when traffic starts flowing normally again. Many data will be gathered automatically and routinely, even for minor incidents (traffic congestion, work logs and work orders, etc.), but the data gathered during a major incident will be even more extensive, and its uses over time can vary. For example, IRT personnel try to scrupulously gather data, including both running comments and supporting documentation like images, in part because there may be a need to bill a responsible party. They will also fuse that documentation with other trusted sources like TMC logs, and details about how long stretches of the road were closed.

An intra- (and sometimes inter-) agency after action review would likely be conducted for an incident of this magnitude. (Several participants did say that their internal post-incident evaluations could be better, however, one even saying "We don't do debriefs.") This is an opportunity for partners to bring together the information they had about the incident–from a variety of sources of varying levels of trustworthiness–and their own perspective on what happened and when. It is meant to be an opportunity to reflect on what went well and what could be improved in the future, so this process must be done with integrity and honesty, but also with an eye toward being understanding rather than accusatory. The broader the circle of participants, the more can be learned, but the more care must be involved.

While it's important to ensure that data is effectively gathered and curated, some participants had the point of view that it was better to start with a wider swathe of information, even if it might be of slightly lower quality, and distill it later. When I asked about this, one participant noted that this was basically the essence of police work anyway, and such processes were to be expected. A similar sentiment was echoed by an IRT driver, who was fairly sanguine about the fact that different people's "sensories" (such as how clearly they actually physically see or hear the phenomena around them, or how granular their time perception is) are different, so some variation in accounts is to be expected.

Temporality is critical for understanding incidents. Some law enforcement organizations put a particular emphasis on debriefing as soon as possible, while memories are fresh. Others deliberately create a bit of distance. A KCM public information professional says he tries to retroactively follow the "tick-tock" or rhythm of the event, as the cadences of information flow, task delegation and

completion, and so on, are an indicator of effectiveness. A WSDOT leader also emphasized that a good post-event timeline helps them to evaluate how effective the actions they took were. There is, it seems, a strong temporal aspect of these reports, both for identifying cause and effect for discrete events, and for understanding the general rhythms of the events.

Working through what happened, with good support of data like the VCC's finalized incident reports, can also offer opportunities for more effective training of staff. One participant noted that documented incidents offered her opportunities for training people, as she could ask them about various counterfactuals (e.g., "What would have happened if X or Y factor had been different?") and thus build their own heuristics and decision-making skills.

Part of the analytical work post-incident is to identify what was part of a pattern and what was a true one-off, state of exception. Both exceptions and patterns can offer significant learning, but have different implications for future planning, training, and assignment of blame [123, 89]. For at least some agencies, one single incident, if it is sufficiently unusual and its records are sufficiently informative, can by itself prompt changes in operational procedure. Thus, the richer and more complete the information gathered during the incident, the more effectively it can inform future practice. The VCC's ability to collect both dispatch data from different agencies, and user-generated data, all with granular timestamps, has already helped agency partners review completed incidents. In this example incident, some of the orchestration of tasks between WSDOT, WSP, SFD, and the Department of Ecology was considered particularly useful to observe, and was later built into a Standard Operating Procedure (SOP).

5.2.7 The Human Toll

What has been described here is important, skilled public service work, with many rationally planned processes and carefully developed expectations. But it's also a very intense social and emotional experience for the people involved.

An incident like this is never a good thing. It will cause frustration, fear, pain, and loss of time and property to many people. However, there are a variety of factors that make for a more effectively handled incident. Clear communication and coordination were the most frequently mentioned factor, unsurprisingly. But interviewees also acknowledged the challenge of accomplishing rich,

effective, complete communication, even though it is so critical. It's a moving target–something will always get missed–but one to stay focused on. As one PIO says, the discipline of taking the right amount of time to enter information helps her and her colleagues get ever closer to their (admittedly aspirational) goal of creating a communication so well structured and thorough, that the recipient has zero questions.

Information itself is not sufficient, either; the same interviewee also mentioned "setting the tone," creating an emotional atmosphere of calm and reflectiveness as well as briskness. Creating the right emotional tone helps people regulate their own behavior, but also bleeds over to others they interact with. Similarly, a law enforcement leader highlighted the toll working on these incidents can have on people who respond to them, and to the victims' families that are "forever changed" by their impacts. Further, multiple interviewees explicitly pointed to the importance of relationship-building and sense of camaraderie, not just among agencies, but among the real human beings who work for them.

Those who are more active users of the VCC, such as one WSDOT leader, expressed a desire to get more insight into what others are thinking and perceiving, and wanted to have a sense that when they are entering information in the VCC, others are actually getting it and gaining value from it. Many people want the satisfaction of knowing they have helped their hard-working colleagues. This can be a balancing act, but another interviewee said that based on their experience, it was indeed possible for members of the TIM-CM operational community to have a robust shared mental model even while being able to focus on their own tasks.

5.2.8 Concluding Thoughts

This major incident, which began with a sudden error (mechanical, human, or both), activated many hours of intensive, varied work by many hands, with thousands of individual decision points, devices, communications, and resources used. Though it began with a very vivid and shocking individual moment, its full ontology was diffuse and shifting, shaped by the people who worked on it and the tools, devices, and processes they brought to bear on it. After active incident work concluded, it began a second life as an item of post-hoc analysis and potential shifts in future investment. Expertise and carefully honed procedure were brought to bear in countless ways,

promoting efficient and effective coordination. It was also a unique event with unique human, financial, and infrastructural impacts, and requiring creativity and tactical flexibility across many work settings. This is the type of work the VCC was created to support and innovate, and the community its development was meant to bring closer together. In the following chapters, I will share what the VCC project helped me to learn about that work and that community.

Chapter 6

WORK INFRASTRUCTURE EMBEDDING IN AND ACROSS ORGANIZATIONS

6.1 Introduction

My research question for this dissertation, *How can designing collaborative systems help interdependent public service stakeholders innovate their shared work?*, asks about how stakeholders innovate their work. But to be able to answer this question, I must address the various embedded work infrastructures which so profoundly shape the internal and shared work of the participating agencies. The people working in these agencies use their own internal configurations of work infrastructures to actually record and manage their work, some of which must then be coordinated with external parties. This chapter is dedicated to better understanding these system contexts, how they evolve over time, and what happens when agencies attempt to share them.

As described in the Literature Review, "embeddedness" and being "built on an installed base" are frequently considered important characteristics of infrastructures, including work infrastructures. However, what embeddedness consists of, and how infrastructures become embedded, are not theorized as deeply as one might expect. Furstenau, et al's [51] dynamic model of embeddedness stands out for its explicitness in this regard. Their work identifies how different systems' characteristics relative to each other lead to different embedding processes. To recapitulate their model, they identify three processes of embedding of individual systems into digital infrastructures. Parallel processes involve systems becoming embedded independently of each other; competitive processes involve one system's "embeddedness" increasing at the expense of another; and spanning processes involve bridges being built between different systems.

This model is valuable, but limited. They follow how individual systems are integrated into digital infrastructures rather than looking at embeddedness as a holistic process driven by the capacities, beliefs, relationships, and goals of the people using the systems. In this chapter, I will contribute to this important but underdeveloped line of inquiry with three additional contributing

dynamics, from the unique perspective of inter-organizational work. These dynamics are more integrated into the characteristics and capabilities of workers, and on dynamics of multi-system work infrastructures, than Furstenau, et al.'s more single-system-focused approach. The first identifies how workers' partial awareness of work infrastructure system functions and data contributes to embeddedness. The second explores the phenomena of decay and new growth, two ecologically inflected facets of the same gradual processes of socio- and technical system change. The third focuses on inter-organizational embeddings, where one organization shares its systems with others. For this last dynamic, I focus on situations where a system's original infrastructural context does not map perfectly on to the organizations where it is shared; but that even imperfect sharings enable the further development of trust, relationship-building, and collaborative work.

This chapter is most directly concerned with processes by which work infrastructure can become embedded, with the development of the VCC serving as a lens on and provocation to these dynamics of embeddedness. As work infrastructure at each agency grows and changes over time, the different types of settings–social, technical, regulatory–the VCC must be incorporated into change as well. This chapter is less centrally about the VCC *itself*, and more about the different shapes of the spaces it inhabits, and how those shapes emerge over time. This offers a unique opportunity to observe different processes of work infrastructure embedding, and add some additional analytical depth to the usually intra-organizational focus of work infrastructure. Because the chapter is laid out topically rather than chronologically, I will not be tracing the VCC's development in this chapter; but where VCC project transitions reflect the phenomena I'm describing, I will touch on them. When I describe the three embedding dynamics I am laying out, I will share anecdotes of VCC development and deployment, when relevant.

6.2 Partial Information and Access

The descriptions of embeddedness of information and work infrastructures that do exist tend to have a relatively simplistic model of realistic use. They analyze the capabilities of systems and the requirements of users, and how connections between systems are established via user need and "design-in-use". But in practice, work infrastructure systems, even within organizations, have a variety of users who don't all have the same understanding of these systems. In many cases, users will partially understand system functions, or have partial access to the information these systems

provide. This affects embedding in a less straightforward manner than a simple inventory of system capabilities would indicate.

6.2.1 Data and Frontline Work

In the public service work context of the VCC, many of the same systems are being used, often in quite different ways, both by "data" workers and "frontline" workers. That is to say, there are people who spend most of their work day inputting and receiving data from technology systems, like WSDOT Transportation Management Center operators or engineers; and there are people who spend most of their day doing hands-on physical work, and for whom IT system use is secondary and less frequent, like SDOT Response Team drivers. As noted by a WSDOT Incident Response Team manager in a 2025 interview, people can have a wide range of comfort levels with technology:

> P11: With any kind of, you know, physical labor based job, we have a range of technical skill. So there are some employees that, you know, struggle to doubleclick to open a folder on File Explorer. And then there are some that, you know, are, you know, incredibly skilled computer users that are doing, you know, 3D modeling, or gaming, or something like that, on their spare time. So, so certainly a range of skills and abilities there.

When studying the use of data-intensive systems, it can be tempting to focus on the experiences of workers whose primary work activities center around obtaining, analyzing, and inputting data– what are sometimes knowledge workers [81], or what I'm more generally calling data workers. A setting like inter-agency traffic incident management, with its complex mixture of worker types using heterogeneous IT systems across different interface configurations, and serving very different modes of work, presents additional complexities that have not been fully studied. The work environments data vs. frontline workers have also change their user experience. For example, Computer-Aided Dispatch (CAD) systems are used in spacious multi-monitor desktop setups in command centers to receive and document 911 calls and to dispatch officers. But versions of the same CAD systems are used on tiny onboard laptops in the field by officers and roving response workers to obtain incident information and record their work progress. Later, analytics from these same systems (e.g., call volume and response time) will be used by leaders to assess agency performance. Unsurprisingly,

different types of workers will bring different expectations (and fulfill different expectations) for system use.

Different types of workers also have different levels of access to influencing their own use of systems and "designing-in-use," and the hierarchies at their organizations place different levels of emphasis on achieving excellent user-friendliness for specific types of users.

These variations can lead to systems being embedded in different ways even at the same organizations. Control room operators keeping a social media feed open to cross-reference with reported dispatch information are creating different connections between systems than the responders who fill in work orders for their on-scene work after cleaning road debris. For example, control room operators often capture and document such social media posts in the same workflows they use camera feeds for, while documenting and communicating about traffic incidents. They typically see information from both sources on the same large screen, or on adjacent monitors. Meanwhile, responders obtain intelligence from social media and camera feeds in often disconnected ways and different interfaces (camera feeds are visible on laptops while social media is usually viewed on smartphones), and are typically not responsible for fusing these information sources in the data they capture.

All of these routines must be taken together to obtain a truly rich and meaningful picture of embedding in even a single complex organization; much less when connections are made between them. Part of the work of co-creating the VCC with the agencies was identifying ways to reveal the value the frontline workers provided, while also being understanding of the institutional logics that led to their partial access. I will discuss this in the following chapter, on collaboration with scaled stakeholders.

6.2.2 Participation in Data Work with Partial Information

Sometimes both frontline and data workers are involved in data-gathering processes that they don't fully understand. For example, in a 2019 ridealong, an SDOT Response Team driver explained that he always took pictures of certain types of incidents and uploaded them to a network drive. When I asked him what happened to the pictures, he said they were sometimes used for a weekly report, but he wasn't completely sure what else they were used for.

This also happens to people recording text. In this excerpt from 2019 ConOps observations, a WSDOT TMC employee described a system called "the log" which consumes data he produces, but which he himself doesn't have access to:

> Dylan points out on his email an entry from "the log." The log is something he doesn't have direct access to, and it's not the same as their incident database. He points out that when they enter an incident with highest priority, it autochecks "send RA report." He says he thinks that this is related to the log in some way, but he's not sure.

Dylan demonstrates an incomplete model of how the data he enters, and the resulting system triggers of entering that data, interacts with another system.

The participants in these examples are managing part of the information architecture for their agency's work infrastructure systems, but aren't expected to follow the full "data journey" they are contributing to. Their personal agency and judgment are not "baked in" to the work infrastructure in the same way as others users' are. The work routines and practices that shape a work infrastructure's embedding, potentially even very important ones, can happen without the full awareness of all users or stakeholders.

6.2.3 Incomplete Knowledge of System Functions

Partial access can also arise from users not being fully informed about system functionality. During an in-person observation at King County Metro during UFR4, a coordinator was asked about policies and procedures, and explained how procedure information was plentiful, but not something coordinators usually have time to fully absorb, and not always in an easily accessible location.

> She points to the shelf on her wall at several thick binders, and says that there IS a procedure book, but she and others don't really have time to look at them. Similarly, a bit later, when exploring the KCM Sharepoint/resources site and commenting with surprise when she finds certain resources, she comments on how many things people don't know exist or don't have time to familiarize themselves with, given all the demands of the job.

Like many other workers, her de facto partial access emerges from the gradual cognitive pruning of information and components she doesn't have to memorize but that do affect her work. In practice, these additional capabilities of her systems may as well not exist during the pressures of everyday work.

Similarly, during a 2019 observation at the WSDOT TMC, I learned about gaps in a flow operator's knowledge of one of the primary systems he uses in his work. The way his workstation is configured shows the State Patrol CAD split into two sections, one with an antiquated tabular view, and one in a more modern UI showing more specific incident details. A screenshot in his user guide depicted a "new and improved" version of the system (replacing the antiquated tabular view entirely) that he could not remember seeing before:

> As I'm pawing through the written guide to follow up from this information dump, I see a page about the "new and improved" CAD. I was surprised to see a screenshot, not only of the specific incident information display I see on Dylan's left monitor (as well as the other monitors), but of an incident log using the same UI!... Surprised, I point this out to Dylan, hoping to get a scoop on why they're using two different versions of the CAD system for different components of their work. He's just as surprised as I am–he says he's never seen that before.

Written guides to system use are meant to serve the function of moderating these partial understandings. Workers can revisit them at any time to refresh their understanding. Yet as seen above, even detailed and well-written guides can fall out of sync with workers' knowledge as they are habituated to a subset of system functions for their work (or are trained by other workers, who also act under partial understandings).

6.2.4 How Coping with Partial Information Shapes Embedding

When people have partial access to or partial understanding of the systems they use, that can influence the practices of use around that system, and how it becomes embedded in an organization. Such gaps in information presentation or mental models are totally commonplace in many work places; they are far from unique to the VCC's user community. I propose that some processes of infrastructuring, which can challenge existing embeddings, happen when the partial information

that users lack becomes salient to their work and when they feel empowered to pursue filling those gaps.

During the demands of challenging and urgent work, it can be easy for a worker to become complacent about the incomplete information presented to them. That tasks are completed on time and to specification is victory enough. In some cases, however, people are more actively cognizant of the gaps in their systems. The WSDOT Incident Response Team (IRT) drivers are dispatched by the State Patrol and its CAD, but prior to the introduction of the VCC, they didn't have direct system access to the CAD. A driver I rode with described how much of an issue that was for his day to day work, as it increased the difficulty of getting the necessary information to approach work scenes fully prepared.

> Currently he and his units have nothing to tell them what's going on, except the WSP radio. He says he wishes he could have even a very bare-bones version of a CAD, at the very least one that would tell a driver what he's assigned to. Usually since there's only one person in a truck at a time, there isn't a person available to take notes on tasks they need to do, and it gets hard to keep track of when a driver has multiple incidents to respond to. Will explains that he can call radio for reminders, but he doesn't think it's a good use of the dispatchers or call takers' time and attention.

This partial access issue was shaped by the embedded practices around radio usage: radio channels to WSP dispatch were considered a precious and scarce resource, so casually calling up to get reminders of incident information was typically avoided. Even more interestingly, it turned WSDOT's virtual message signs *into* a kind of work infrastructure for IRT. (These virtual message signs (VMS) are the highway overhead signs that WSDOT uses to advise drivers with messages such as "CRASH 1 MILE AHEAD, SHOULDER CLOSED".) This is because IRT drivers would sometimes see the messages flashed on those signs as they approached a scene, and triangulate it with the dispatch information they would otherwise radio in for. This even happened while I was doing a ridealong; the driver expressed relief that a sign he noticed was obviously connected to the incident he was dispatched to, since it made it clear to him how far ahead the incident was. However, this was to some extent serendipitous; such signs are not always informative enough or noticed in time.

When I conducted my workplace observations, I was encountering long-running processes. The introduction of the VCC allowed me also to observe how such processes can begin, over a shorter time scale. Understanding and coping with relative gaps in information is already happening for the VCC's user base, across agencies. The VCC's dispatch feed *itself* only contains partial information, as the origin systems intentionally filter out irrelevant or sensitive records. Yet some VCC users, such as WSDOT TMC flow operators, do have broader access to some of these records, as they can view a less redacted feed of the WSP dispatch on their agency's own systems. On occasion, they create VCC incidents based on these WSP dispatch records that aren't in the VCC, manually inputting relevant information from those records, to allow users at other agencies/locations to view enough information to support their work on that specific incident. Because of the complexity of incidents, the universe of possibly relevant information is vast, and even records that are usually of an irrelevant type can contextually become relevant during specific situations. Being able to navigate this challenge successfully means that each participant in an incident is also, in some ways, acting as a filter or qualifier of information they have relatively more access to.

Overlapping Partial Access: Competition and Triangulation

Another version of this pattern occurs when people have access to multiple systems that have partly overlapping information. As people become aware that there is additional information or functions that would allow them to do their work better, they exercise their (varied levels of) agency to preferentially use the more complete systems. In a 2025 interview, an IRT driver explained that the VCC can allow them to see WSP CAD records slightly before the drivers would otherwise be dispatched by WSP on the radio:

> Ridley: Thinking about the other communications or IT systems that you use, how does the VCC currently fit into those systems?
>
> P11: Yeah. So, if, if you are an incident response worker in the field, you're, you know, hopefully, I would say, probably 90% of the crew has it open 24/7 while they're working. And they are using it to, to track, you know, and locate and respond to incidents in the field. Oftentimes, you know, a pin will pop up before it'll be dispatched by State Patrol. And so, you know, if you're really on the game, you can just watch for a pin to pop up.

> Same thing, you know. Maybe you're out, you know, changing a tire, and you don't hear on your radio that something was dispatched. I always like to, when I get back in the truck, look over and say, Oh, there's a pin there, let's see what the pin is, and, and see if it's, you know, relevant to our work. Daily, you know, for, for VCC interaction, It's certainly, it's a source for any, you know, our primary CAD feed for State Patrol, right? So we view that. So you know, we're, we're constantly utilizing that function of it.

Awareness of partial information, and appetite for greater completeness, can be one driver of what Furstenau, et al. refer to as "competitive" [51] embedding processes. This "competition" can be won based on sometimes very minor variations in capabilities. In this case, the "competition" is even multi-modal: information comes in via both visual and audio forms, and the VCC's visual display of the CAD occasionally wins out over the verbal radio protocol by which they are usually dispatched.

However, what viewing this as purely a "competitive" process misses is the importance in many types of work of redundancy and triangulation. As noted by Chisholm [25], robustness or redundancy are often valued by government service organizations more than efficiency. Having multiple systems available which serve similar purposes can genuinely be frustrating and lead to cognitive burden [4], but it also builds in some safeguards that allow people to carry out their mission. Being able to investigate similar information in different systems also provides additional avenues for triangulating and validating information, which is so critical in fast-changing, high-urgency incident work, where different channels capture different aspects of the same information, at different speeds and in different modes. In this sort of work, competition and triangulation can coexist; and deficiencies in one system can be propped up by the capabilities of another. Rather, competing systems can sometimes function more like a toolkit, which users draw from strategically as needed.

6.2.5 Decoupling of Information and Work Over Time

Work infrastructure system elements often change more slowly than work practices. Partial information and access can result from the gradual decoupling of the information actually being

presented in a system to the work it supports. At some point, each interface element of a work infrastructure system was designed to communicate some relevant information to users. However, that signal is not necessarily retained during the work infrastructure's lifespan. In the following example, a visual indicator showing in a KCM system (a curly bracket around a timepoint indicator) has lost its meaning for a worker viewing it:

> I notice in the "schedule" column some timepoints have parentheses around them, including some with curly brackets. I ask Lisa what that means and she says she's embarrassed to say she doesn't know. I reassure her that there's no need to be embarrassed, that systems this complex often have lots of little things that aren't relevant to the people using them so there's no real reason why they should know about them. She says "John" could answer that; she's not a techie type, that she's more into policy and procedures. ... She beckons over Frank, and asks him what the brackets on the schedule mean... He confidently says that they used to indicate estimated timepoints, but now they mean absolutely nothing. I ask why that wasn't fixed, and they both seem amused/bemused. They say they have to pick their battles when it comes to things like that. For example, they used to be able to right click on the block display and create a CSR from that, but that functionality broke.

In the example, the visual indicator is essentially discarded from active processing and interpretation by the worker. Uses and mental models based on those partial understandings can get entrenched as well, which means that idealized models of system usage based on user guides, standard operating procedures, and vendor contracts can slip away more from users' actual perceptions and actions using those systems. What is being embedded in practice is a kind of alternate version of the official system configuration. This can be seen as an almost "holographic" form of work infrastructure, but one with real consequences. Since work infrastructures often have long lifespans, these holographic partial understandings can have potentially long-ranging impacts.

6.2.6 Partial Access as the Baseline

Partial access is a challenge and a source of friction. Yet people act with partial understanding frequently, and are able to successfully complete their jobs ["assigned tasks"] most of the time. I

say this to emphasize that partial access is the rule for many kinds of work and workers; it is the mundane truth, not an unusual exception. It constrains and shapes the routines of system use and information access; it characterizes the "installed base" of work infrastructure just as much as the system's full capabilities would. It helps to create the kinds of interpersonal connections that build the network of informal coordination, as people with more access help each other gain access to information or understand its use. A truly sociotechnical view of embedding must take this reality into account when attempting to explain what embedding is, and how it does and does not work.

We often think of the metaphor of imbrication as being one of ever tighter and more densely layered structure, as the social and material "talk back" [112] to each other to create the sociomaterial. However, imperfect knowledge and incomplete implementation of systems into different locations, and the patterns of use that emerge from that, can also create "tunnels" through that imbricating structure. People develop work practice in reference to the lost signals of the systems they use. A micro-example of this in this chapter is the vestigial parentheses on the KCM CSR system, which is essentially disregarded and forgotten. More vividly, the IRT drivers' pattern of refraining from contacting WSP dispatch for incident details caused the overhead highway signs to be incorporated into their work infrastructures–that was, until they had the VCC. When organizations are making decisions about future technology investment, the stability of these "tunnels" can make it somewhat more difficult to see the gaps, especially if the people maintaining them are lower-powered or non-data workers. Taking on a project like the VCC can, under the right circumstances, bring some of these sociomaterial structures to light, as people attempt to explain their work to others at other agencies, and make these partial forms of access and the related work processes more explicit.

In this section I have reviewed several variants of partial system and information access, and explained some ways they influence system use and, in turn, system embeddings. Partial access, it must be emphasized, is not pure *lack* of access. It is a meeting of a person's work functions and a system providing some, but not all, important information or capabilities for that work. People then must try to either fill in the gaps, rethink their own work to fit what information they do have, or participate in design-in-use. They may also miss out on information being conveyed by systems, which then reshapes the way they carry out tasks. As new employees are brought on and trained by existing employees, these patterns perpetuate, and systems continue to be embedded by practice

and worker understanding, and relative availability of information with comparable systems.

6.3 Re-evaluation and Re-appropriation in Response to Other Changes in Practice

In addition to partial access, organizational strategy and policy can change how systems become embedded. For example, the VCC has some built-in incident reporting features, which collect data generated during an incident into a .zip file containing a spreadsheet of timestamped incident actions, and a folder of files users have uploaded, if applicable. A King County Metro leader explained during our second evaluation phase in 2023 that this feature was as yet untapped at KCM, but that upcoming policy and workflow changes around reporting in the agency in general would likely change that. This potential revisiting of specific system functions can be hard to identify as an outcome or benefit *during* a design project, but the end of the design project is often only the beginning of a work infrastructure's long and complex life.

Changes in uses of other extant systems can also create conditions of usage that reshape system embeddings. The re-appropriation of an existing tool (Microsoft Teams) to new functions at the SDOT Transportation Operations Center prompted comparison to the VCC–especially since this is one piece of work infrastructure whose internal policies make it harder for SDOT personnel to collaborate with an external partner.

> I ask about their use of Teams as I see that Malik has it open on his desktop. He says they use it quite a bit to communicate internally with PIOs, signal timing engineers, executives, SRT, etc. They have pre-set groups so this makes communication easy. Send updates, photos, etc. Malik considered the VCC as a Teams-like environment with more features (e.g., ability to collaborate with WSDOT who is not "federated" so they can't use it to communicate with them). Email not really used any longer to send out updates since we have Teams.

What both of these examples show is that technical and policy processes imbricate with a work infrastructure's context of use, allowing different system features to become activated or more salient at different times. This can change the ways systems are embedded and how their fortunes change in an organization. Changes in approaches to reporting can make a previously unused reporting

feature in the VCC more appealing; a greater internal use of the communication features of Teams highlights to SDOT personnel how much better communication could be with external partners.

6.4 Optionality and Ambiguity as Strategies for Embedding

In prior sections of this chapter I have discussed how partial system or information access becomes a core part of the embedding of work infrastructure systems. In this section, I will talk about a different sort of process I was able to observe through the VCC design project. The VCC was a system that the participating agencies agreed to participate in co-creating, but were also assured that any specific usage would not be externally mandated. This unusual arrangement allowed me to see what happened when a new system with many possibilities, but with few firm requirements for use, was brought into different organizational contexts. The "optionality" or ambiguity of the VCC's scope of use provided different opportunities for infrastructuring and embedding.

Because the VCC was incorporated into different organizations with different needs, resources, policies, and processes, it became much more obviously "work infrastructure" at some places than others. For IRT drivers, it became a core part of their work even without being imposed "from above." For WSDOT and SDOT control room operators, adding information to VCC incidents became a standard expectation.

However, other agencies and workgroups held the VCC more at arm's length. The Seattle Police Department, for example, helped to establish a data connection from its CAD system into the VCC, but has almost no active users and virtually no data entered into the system by those users. One SPD leader who was a great champion for the VCC, though not personally an active user, mentioned that SPD would have detached from the VCC process very willingly at his personal judgment. The Seattle Police Department also had logical reason to be hesitant to fully participate; fear of exposing the department to accidental violations of criminal justice information standards was a reasonable response to another potential form of data exposure. However, the VCC was something this officer cared about, and his personal buy-in was invaluable:

> P8: Well, I think it became clearer and clearer, and I think we kind of aligned our different parties, kind of aligned how the project was gonna move forward, and what our intention was. The goals to produce a product that would be useful to all of the

> parties involved and perhaps even more than that. But, I think it's clear that, when dealing with a number of different agencies from different levels, that bringing parties together with the common understanding, and an ability to integrate the different pieces of technology and authorities would be significant. And it was and continues to be a problem. ...
>
> Ridley: As those organizational and political changes were happening in your world, you know, and the VCC was also developing in tandem with that. How did you see that evolution happening? Like did you see changes in the VCC's project management or kind of scope of features as that was happening?
>
> P8: I–I thought that there were some real heroes in the VCC that really drove that project forward... And, [pauses] You know, in my mind I could have told at any point during this thing I could have told my boss, I don't think this is valid and I want to step out. Or, I think SPD should drop out. and they would have gone, OK! and it wouldn't be a problem. Which would have been terrible. And that's not how I feel. I feel strongly about the project, and that's why I've kind of continued to participate all along. ... This is probably a reasonable time to say that each organization who's participating with the VCC has been asked to sign memorandums and to provide information so that there can be information sharing from the computer aided dispatch, and that sort of thing. And there has been and continues to be a resistance to that from the Seattle Police Department, towards providing that information for fear of violation of CJIS, criminal justice information sharing rules, which would then prospectively cause the Seattle Police Department to lose its license to have access to that information. So it's a high sensitivity.

A significant part of the value of the VCC to this interviewee was in part what its functions and the shared work of developing it *signaled* about collaboration between departments and agencies, rather than its direct instrumental value for SPD's work tasks. Its ambiguous placement in the organization, and its relatively *non-central* role as work infrastructure, allowed it to serve a different and more expansive role in this officer's estimation.

Can this be seen as a type of embedding of work infrastructure? If so, it runs counter to the way

work infrastructure is typically characterized. It provides a more rhetorical, political, and visionary capability; its very flexibility and ambiguous context of use create a rhetorical space for the VCC to align with individuals' political goals. Yet it is also, for this same flexibility and ambiguity, a site of risk and danger for a cautious organization like the Seattle Police Department. Further, its utility for rhetorical purposes was also *tied* to its instrumental purpose. Had the VCC project as a whole been a failure, or the system been useless for many users, that would have also reflected poorly on the collaborative project as a whole. The work of SAJOG to reinforce at its regular meetings the instrumental usefulness of the VCC to the attendees is a kind of "proof in the pudding" for the political goals it is connected with.

In an inter-organizational environment, work infrastructure can't have a single identity or structure (since the concept of work infrastructure is so connected to particular practices and adaptations by people acting within organizational structures). However, the ability of a multi-organizational system like the VCC to connect and support rhetorical framings of system use, and to exploit their more ambiguous position in an individual organization, can be a tool of infrastructuring even within organizations. However, each organization may have a different level of flexibility to utilize a shared tool like the VCC; organizations where the culture is very intolerant of uncertainty may be able to gain less value from this mechanic of infrastructuring.

6.5 Decay and New Growth

The VCC project afforded me a perspective on several different organizations at the same time. The public service organizations participating in the VCC project are large and conduct many functions. They typically have hundreds of employees and sometimes dozens of distinct divisions. Moreover, even within an organization, funding and projects can come from different lines authorized by separate legislation. This can lead to uneven technology investment and refresh cycles.

This heterogeneity can make it relatively easy to observe what I call processes of "decay" and "new growth" in work infrastructure change over time. Here I define "decay" as the gradual and ever-present degradation of system functionalities, either directly (e.g., as a result of devices physically wearing out) or indirectly (e.g., from gradual "bit rot", loss of functional compatibility with currently maintained versions of software, or drifting apart of system functions and work practice), within the context of long-term, persistent work infrastructure systems. Similarly, "new

growth" is the gradual evolution of new capabilities, extensions of pilots to full programs, and any number of non-routine patches or expansions that allow such systems to acquire greater "life" in the organization.

I am not the first to use this notion of "decay" to describe this kind of phenomenon; for example, Cohn [29] and Ramakrishnan, et al. [119] have used similar terminology. Cohn's concept of "convivial decay" arose from her study of an aging infrastructure supporting a space mission to Saturn. This end of life "repair-into-decay" performed by system maintainers marked a shift from a mode of repair to keep the infrastructure going, to one where repair was meant to help it gracefully reach the end of its life. From observing this process, Cohn identified how "rather than infrastructural decay being a natural by-product of time's passing, there is active work that goes into producing a convivial decay in which the multiple temporalities of aging and decay are brought into alignment through negotiation of what aging means, its impacts on different forms of work, and even what counts as old and new" [29].

In a context like traffic management, there is a different kind of orientation to work, embedding, and system use, leading to a somewhat different perspective to Cohn's. In this context, systems are used more continuously, with uncertain lifespans not connected to specific projects but to ongoing daily work. The systems that are decaying are interconnected with other systems to create a persistent overall work infrastructure, so the meaning and management of "lifespan issues" is different. The strategies of maintenance, and the mechanics of decay can differ; the notion of new growth in particular may not apply the same in such situations, or even be seen as an obstacle to convivial decay since it may be seen to artificially prolong a graceful death. So what decay and new growth mean in relation to each other connects to the actual kinds of work the systems support.

When work infrastructure systems decay, they lose part of their "vitality" in the organization. This may happen because they are no longer backward compatible with newer systems, and have degraded functionality. However, the decay is not located strictly in material characteristics of the systems. It can also emerge from a gradual loss of fit with work practice or policy guidelines, or even conventional practice in the domain. Further, decay and new growth are ultimately a part of the same overall process of systems and organizations that use them changing and adapting to each other; new tools and workarounds often adhere to the same sites where decay is happening.

Functional decay is not limited to gradual decline or deprecation of existing features, or back-

compatibility issues when updating hardware. It can also emerge from a tightening of organizational policies, such as the greatly reduced use of Microsoft Teams at Washington State Patrol. In a 2025 interview, P16 explained that Teams chat had been disabled for WSP, requiring a search for a potential replacement:

> P16: Oh, Teams. Can't forget about Teams.
>
> Ridley: Oh yes. And so do you use like, the sort of chatting feature of Teams or is it mostly meetings?
>
> P16: We used to use the chatting feature, right up until our current governor expired all of that information.
>
> Ridley: Ah.
>
> P16: So we no longer use Teams for chat. All that has been disabled.
>
> Ridley: Really.
>
> P16: In the interest of, yeah, it was in the interest of public transparency.
>
> Ridley: Was there rationale given for that?
>
> P16: So they have turned off all Teams chats and they turned off iMessage on our phones. And right now they're researching communications collaboration tools. I know one of them that shows some promise is Genasys Connect. Which would be nice if that could be tied into a VCC type thing, where if a VCC event is created, it automatically creates a Genasys chat room which allows people to post pictures and takes the next step up, if you will, to VCC.

This created a new prospective gap that other systems might be able to fill. In the context of this conversation, it enabled a comparison to the VCC. The VCC's more flexible and user-centered development structure meant it might be able to fill some of those gaps more readily than internal systems could.

Such policy changes can cause integrations or external connections to fail in the same gradual, quiet way as more system-driven decay processes, as it can take time to recognize and cope with

these changes (and alert external partners, where relevant). This form of decay also helps us to see why "decay" and "new growth" can be seen as different faces of the same process. From the organization's perspective, these kinds of policy changes can more readily be seen as unalloyed "growth" because they tend to mean better compliance with security guidelines.

Viewing "decay" and "new growth" together as a kind of shared ecological process offers analytic value because it emphasizes the dynamic stability of work infrastructure. This creates openings for what might be called "re-embeddings," or re-workings of embedding processes for particular systems, as their broader context of use shifts. This can challenge existing configurations of embedded systems and work practice, but can also create new places or "niches" for change. This bears some resemblance to "infrastructural grind" [74] discussed in the Literature Review, where two information infrastructures grind against each other, and "potentially how new technological infrastructures succeeds in penetrating the new domain." However, while decay and new growth also put changing information infrastructures into interaction with each other, it need not be as "smoothing" or "subtractive" as grinding, nor does it necessarily create a space for "penetration"; but rather, it provides the dynamic evolution and adaptation of niches. It may also inhibit the eruption of "points of infrastructure" [117], which would otherwise lead to more typical infrastructuring activities. Rather than a situation where a "new awareness of the now-visible infrastructure results in a stronger sense of urgency regarding infrastructure improvements: the breakdown must be fixed, but how?" [117], an evolving niche may come into the right configuration to shelter the breakdown from view and diffuse urgency.

6.5.1 Heterogeneity of Decay Within Organizations and Systems

The metaphor of "decay" is one of a complex chemical and biological process that often does not affect an organism in a homogeneous way, but in asymmetrical "chunks" or "lumps." Analogously, processes of decay and new growth can happen in a heterogeneous way even in the same organization. This can also lead to different paths for seeking support, as older systems may have legacy or one-off support processes that don't apply in every system or use case. In the excerpt below, I learned about the histories of critical software and hardware–work infrastructure by any reckoning–at King County Metro Transit. Like many such systems, these systems are both old chronologically

and have complex paths to repair and assistance:

> Steve and Joey explain that in about 2012, ITCS was created for them by Init to mimic [their word] their old in-house system, MMI (Man-Machine Interface...[They] say that the old system was a lot easier to use, with many tasks requiring fewer clicks; I commiserate, saying it's hard when a new system comes on and things get slower. Steve explains how when there's a problem with the system, they have to call their tech people (OTT), which calls Init, which is in Germany. That causes some time zone issues, and sometimes they can't get assistance quickly, when before they could simply walk over to the server room and press the button to restart it.
>
> ...They tell me a little more of their infrastructural history. Apparently the phone/switchboard system they have was already out of date when they bought it. I laugh incredulously, and they say they were warned by the maker that they wouldn't be able to support it; Joey wryly says that they used to get service at Radio Shack but obviously that's not an option anymore either.

However, at this same observation, I toured their fairly state-of-the-art seismic protection server room, one door over. This disparity speaks to how varied the institutional logics can be regarding the maintenance and investment in technology, even within one organization. Like many agencies, KCM cannot be accurately described as either outdated or up to date in its use of technology, but an ever-evolving blend of the two. This perspective of decay avoids a simplistic characterization of organizations' different work infrastructures or technological advancement, in favor of one where dynamic processes of decay and new growth affect different components of the organization at different rates and under different processes.

This heterogeneity is exhibited not only at the organization level, but sometimes even at the individual system level. Different parts of a single system also don't always degrade at the same rate. In the example below, the Fire department's onboard system in their engine vehicles is still effective at displaying call information and adjusting the interface automatically when the call status changes. However, the mapping component is so unusable that the firefighters have to use Google Maps on a cell phone to adequately get to and identify the incident location.

> We get out of the vehicle and I'm given a little introduction to the onboard system. Evidently it has a lot of great tools; it will automatically display information about the call the unit is dispatched to, allow the firefighters (I should note that the fire trucks tend, in my n of 2, to have two people rather than one) to indicate they're on their way, and default back to a tabular incident view once they've resolved the issue. It even has a mapping tool; but he points out that the mapping tool is so excruciatingly slow– demonstrating it, as we watch for 30+ seconds, and the map is completely frozen—that they usually use a phone and Google maps if they really need directions to a call.

Components of a system that are more data intensive (such as map rendering) or tend to follow a faster industry refresh cycle are more likely to decay more quickly than more stable, less data intensive components. Compensations and workarounds, like the use of Google Maps, can disguise this heterogeneous decay.

Cohn also calls out the heterogeneity of infrastructural decay in slightly different terms; that it is composed of "multiple lifetimes of different parts of the system – hardware, software, code, organizational processes, programming languages, institutions, careers – all of which are entangled and are aging or obsolescing at different rates" [29]. The difference in focus here is that, again, this heterogeneity in persistent work infrastructure configurations can make the work infrastructure susceptible and salient for infrastructuring differently.

6.5.2 Decay and New Growth Influencing VCC Usage

The VCC project's post-deployment evaluation period offered the opportunity to start observing aspects of this process in action with a brand-new system, suggesting that it is a process that can begin very quickly after a new system is implemented. "New growth" could already, as of my 2025 interviews, be seen to be subtly shouldering some aspects of VCC functionality aside. For example, an IRT interviewee discussed recent investments in sharing WSDOT camera feeds with IRT personnel in their vehicles, which are already supplanting the once uniquely useful VCC camera tools:

> P11: And then the other is a uh, Synology surveillance station server that we have essentially set up. And it basically just takes a recording of what a particular traffic

> camera is viewing, and then rebroadcasts it... Okay, yeah. So this is kind of, you know, what it would look like. I mean, we're just viewing the the big screen right now, but if we can go to like a particular milepost on I5, display all the cameras that have been migrated to this technology. I believe it does take some, some installation in the field of some equipment...And so this, this basically would enable an IRT worker in the field that does not have permissions to access The TMS home built DOT camera feed, or camera management program, which would, you know, let you rotate cameras. Um, you know, we, we don't necessarily want everyone to have access to that. But this program would let people go and, and be able to check whatever camera they wanted to: "Okay, I'm looking for something on the main line. It's flowing here, so it must not be an incident on the main line."

The Synology system was described as a pilot program still being evaluated, but the interviewee expressed confidence that the program would be institutionalized. The capabilities of this new system are more powerful and flexible than the relatively simple, image-only traffic camera tools in the VCC. While the VCC is still acknowledged to be a valuable tool for IRT, its value proposition is slightly shifted for IRT drivers specifically with the introduction of this new system.

Similarly, in another 2025 interview, an SDOT TOC operator discussed how a previously used system (Viewpointe, which aggregated SPD and SFD dispatch feeds) had gaps that VCC filled, allowing the TOC to move away from Viewpointe. However, now, some of those functions the VCC fills might be out-competed by an even newer system called ActiveITS. Once it does, he claims, the VCC will revert to its *original* scope of use and not be "overused" as much:

> Ridley: And the ActiveITS system that is currently being like, built out. You mentioned that it's eventually going to hopefully have like, more CAD feeds in it. Do you think that there will come a point, a time in terms of its maturity, that the function that you're using the VCC for just general situational awareness of the CAD feeds that that'll be like replaced by ActiveITS or do you think that there's enough non overlap that it wouldn't?
>
> P5: No, I mean for the CAD feed. I mean, definitely. If we get more information, we're gonna, it's gonna be replaced 100%, but VCC is still used, going to be like, the same

> initial, how it was launched, which is like a virtual, virtual coordination center. I think we've been using it more than what lately, because we have, we lost the CAD feed. We've been overusing it. But we're just gonna use it as what it was intended to from the beginning.

In a different part of the interview, the same interviewee expressed that the VCC was *underused* by the VCC userbase in general. So for this interviewee, "underuse" and "overuse" are both highly relative to the contexts of the tasks being done and the relative availability of systems to complete the task. The VCC's ability to help SDOT TOC cope with partial information was seen as an "overuse" corrected by the introduction of a more appropriate and sophisticated system. This suggests another expression of "infrastructuring": not only reappropriating or improving or creating workarounds for systems, but also rethinking what are the appropriate scopes or boundaries of the systems in reference to the work they support.

6.5.3 The "Forest" of Multiorganizational Work Infrastructure

In a dynamic and emergent multi-organizational system, where one agency's operations and system use can be influenced by the multiorganization's operations and system uses and where infrastructural "inertia" can drag in multiple organizations, the ultimate unity of decay and new growth processes is even more clear.

When trying to map out the current state of a multiorganization's various work infrastructures and common knowledge, the greater number of organizations, workgroups, and systems means there are more concurrent changes happening. Early in the VCC project, I gained an appreciation for this when conducting a "system inventory" of the agencies where I was doing workplace observations (King County Metro, SDOT Transportation Operations Center, WSDOT Transportation Management Center, Seattle Police, Seattle Fire, and Washington State Patrol). This inventory consisted of, along with my field notes, writing down the names and primary usages of the technology systems that I saw or were mentioned by users. Many of these systems, such as the KCM CSR system or the SDOT TOC Viewpointe tool for viewing Fire and Police dispatch records, were work infrastructural systems with long lifespans and vendor contracts. Further, the IT departments at the agencies, particularly at the City of Seattle, were also undergoing reorganization and centralization, which

affected how the agencies were able to both serve their own internal customers and interface with external projects like the VCC. Major overhauls in each system or IT organization were considered significant undertakings for the individual agency. Yet because there were so many systems and contexts of use, I learned of major changes that were happening to several agencies at the same time. As the VCC project continued, this system inventory was refined and used as input to the design team's conversations with agency IT, and had to be edited several times in only a few years to maintain even a rough semblance of accuracy.

Each major work infrastructure change an organization undertakes is a *specific* and relatively rare event. However, if there are seven or ten organizations participating in shared work, each of their individual organizations' refresh cycles must be overlaid on each other, meaning that such rare and occasional changes are actually far more frequent when "zooming out" to the level of the multiorganization. There is much more total motion, more total decay and new growth happening at the same time, than can easily be seen from the perspective of a single organization. So, on any given time scale, it is easier to observe than it would be within a single organization–and more possible to see as a gradual and ubiquitous process rather than only as a collection of large and rare system update projects. We might, then, view multiorganizational-level work infrastructure as a "forest": with its large and interdependent collection of organisms rotting, feeding or predating each other, metabolically communicating with each other, and always reshaping its own boundaries through these processes.

Viewing the system of multiorganizational work infrastructure this way is meant to be an analytic lens to notice important dynamics, and appreciate the complexities of their interactions. It is not meant to be a replacement for existing frameworks, but a complement to them when viewing system use, coordination, and operations at this scale. It can also offer an approach to understanding the often peculiar temporalities and lifecycles of infrastructure systems: less as well-defined, bounded projects, but as a part of the slow and gradual emergence and evolution of organizational practice and identity.

This raises a key analytical question, without which this concept could easily become "overgrown," so to speak. That is, how do we know when we are observing an actual "forest" of interconnected, inter-organizational infrastructures, and not merely taking advantage of the relative law of large numbers? Certainly, if one polls enough organizations, even if they are not related

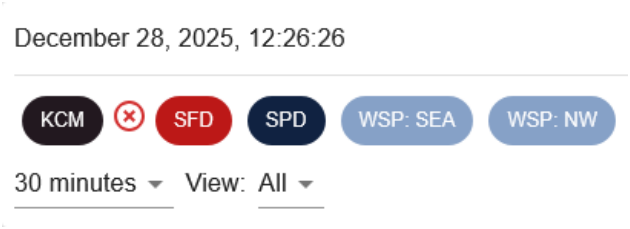

Figure 6.1: Labels at the top of the Integrated Dispatch Feed, showing that the King County Metro feed is currently down via a red X next to its label

in any meaningful way, one will note elements of decay and new growth. Further, the more organizations one polls, the more likely there will be functional or system overlaps in some respect. To analytically demarcate where we might find a forest, we must look to the same general rubric we would use to identify a physical forest: some meaningful degree of interdependence.

In the literature review, I examined several approaches to organizational *interdependence*, including process, policy, relational, and system aspects. As a multiorganizational work infrastructure "forest" evolves, it contains aspects of all of these forms of interdependence. Both shared operational needs of interdependence and the trust enabled by it allow the system's interdependence to grow.

For example, once the VCC was in use, users could see when the CAD feeds from each of the source systems were malfunctioning (when a feed is down, there is a red X next to its name on the Feed), giving a glimpse into the technical status of other agencies. An example is shown in Figure 6.1. This could be seen as a kind of "suture" (recall from Cabitza, et al. [19] how "sutures" enable visibility into connections between interdependent systems) between the participating agencies, giving all users a bit of insight into how the data flows that contribute to the feed occasionally break down.

A new system like the VCC can also change the fortunes of individual work units in ways that extend beyond that system's boundaries. A particularly striking example of this was the experience of WSDOT IRT, who prior to the VCC did not have onboard internet in their patrol vehicles. The usefulness of the VCC, which requires a consistent internet connection, was noted as a contributing factor to making the case for them to finally get onboard internet. Phenomena like these point to the potential existence of a multiorganizational work infrastructure "forest."

6.5.4 Temporality of Decay and New Growth Processes in the Forest

System decay is a process that happens over time, and its temporality is one of its key characteristics; how quickly "slippage" [29] of system capabilities takes place changes not only how visible that slippage is but how urgent it is perceived to be. How should we think about the temporality of decay and new growth? Ramakrishnan, et al. [119] use this concept of gradual declines in infrastructure to analyze the "temporal fragility" of infrastructure, to challenge the notion of infrastructure as obdurate and complete. However, their framing is different in an important way. They explain that "while decay, maintenance, and repair simultaneously coincide, yet retain their distinction as temporal phases in an infrastructure's life, thinking through configurations brings the temporal and material together as well as granular embodied labor and systemic power relationships." Concerns for the temporal and material, and embodied labor and power relationships, are indeed critical. However, I find greater analytic power for my analysis by viewing processes of decay, maintenance, and repair as more directly interactive at both short and longer time scales. This is because they affect each other, particularly as one zooms out to systems of systems [109]. Maintenance, for example, can prop up the decay of systems until their utility is extinguished. Repairing a system that has partial information overlaps with another can hasten the demise of the un-repaired system, as it becomes relatively less useful. And it is even relative: what functionally acts as decay for some users, such as policy changes that degrade functionality, can be viewed positively by other parts. As people come to work each day and try to use the systems they're afforded to do the work they're assigned, all of these dynamics affect them at once, because they all have functional and cognitive impacts on the completion of actual tasks. Moreover, in the multiorganizational "forest," these interconnections multiply and become even more difficult to usefully order sequentially.

Cohn [29] comments that

> It is not surprising that there is little research on dying infrastructures, since we might assume that something that is coming to an end has little insight to offer about current or future practice. Yet this assumption is premised on a progressive account in which dying systems are those that have ceased to be relevant...This is a view in which the past is irrelevant, except as a form of historical narrative to understand how we came to be where we are...Obsolescence, degradation, and decay, according to this view, would

be merely a natural by-product of innovation and time's passing and would not require explanation on their own terms

Not only does analyzing these phenomena on their own terms and times valuable, but zooming out to the level of an inter-organizational "forest" can reveal forms of resilience and dynamic stability that better help us understand the lives of systems and those who use them. The following section examines one particularly important form those interconnections can take: the embedding of distal systems.

6.6 Inter-agency System Use: Embedding Distal Systems

In this section, I will describe how such inter-agency systems have been embedded in different contexts, establishing a model for "distal" embeddings of systems that are developed in one organization and shared with others. The findings in this section came about through my attempts to get a better understanding of how the agencies were already coordinating with each other when the VCC project started. On the design team, we investigated current technology connections between them, and tried to inventory those connections and follow the data journeys [11] into and out of them. When we designed the VCC, we could then benefit from the valuable parts of those existing patterns and also identify additional information and process gaps the VCC could potentially fill. The VCC's development is thus (in a sense) "embedded" into previous inter-organizational histories of development, both successful and unsuccessful.

Many of these systems directly support collaborative work or shared situational awareness, such as a "common operating picture" (COP) tool meant to help Seattle Police and Seattle Fire better share incident information and analytics. This COP system is not in significant use by the SPD or SFD personnel I spoke to, and according to an SPD interviewee, fell out of favor among the police when its greatest champion left the department. Some systems are shared when one agency must undertake a certain kind of work, and borrows the use of a system created in another agency for similar work, but where the system doesn't support direct coordination between the two entities. An example of such a system would be Sector, the driver ticketing system developed by Washington State Patrol and shared with Seattle Police. While the two agencies use the same system, there is no shared ticketing happening. Yet others enable cross-referencing of records, like cross-referenced

work order numbers that the SDOT Response Team occasionally sends to Seattle Public Utilities.

6.6.1 Cameleon

While each of these inter-agency system-sharing examples has unique and interesting characteristics, I will only go into detail about one specific example, the traffic camera system called Cameleon. The Seattle Department of Transportation's Transportation Operations Center (SDOT TOC), like the Washington State Department of Transportation's Transportation Management Center (WSDOT TMC), operates many CCTV cameras that continuously watch areas within their respective jurisdictions. From the TOC, the primary "home" of the Cameleon system, operators manage metadata about their several hundred cameras (their location and labels), coordinate servicing them when needed, and most relevantly for this discussion, remotely reposition them when needed to provide the best possible view of traffic conditions. These cameras are trained on roadways under the City's jurisdiction, but because of their placement, some of them can also be made to view parts of the State's roads (such as Interstate 5). The Cameleon system offers some other functions as well, but I will focus on the movable camera feeds. Several VCC partner organizations have been given partial Cameleon access, so they can improve their own situational awareness of real time traffic conditions in the Seattle area.

Cameleon's original context of use–SDOT management, mostly from within the TOC, of its own roadways and equipment– is partly lost when it's ported to another agency. Most external users don't have the time to exhaustively investigate the best ways to make use of the system, or have easy access to tech help for it. As these layers of uncertainty pile up over time and people are busy with their primary work tasks, people can even forget how to engage with it, such as this experienced SFD operator who doesn't even remember how to log in to Cameleon:

> Chris has had almost 40 years of experience. He, too, isn't quite sure how to use Cameleon or even remember what the password for the system is. He tells me in a couple of minutes that he talked to two other people and they don't know either. I ask when they got access to it and he claims it was only a few months ago, but he'd been away for a while before that.

Because the borrowed system has to get incorporated into a deeply entrenched installed base,

its means of access in a secondary environment can be prohibitively awkward and strange for some users or potential users. For example, in a 2019 observation at the TMC, an operator mentioned potentially having a login to Cameleon, but couldn't log in without a specific flash drive, which he didn't have with him. So, as with internally created systems, users sometimes seek publicly available alternatives as workarounds. Several participants, for example, mentioned using the SDOT publicly available travelers map (which has some camera feeds) to monitor SDOT cameras, rather than using Cameleon. The occasional bugginess of Cameleon was also part of the impetus for a WSDOT employee to try to create a tool aggregating camera feeds across agencies, as reflected in a UFR4 observation:

> John is working on a system (PTZ6) that connects all the cameras in the state so that all users can go to PTZ6 to see all camera feeds. This system currently exists but it's very clunky and John is working to redesign it and make it available to all partners. ... SDOT camera feeds don't appear to be working and the public URL has video for many cameras now.

Yet, despite its issues, this kind of technological "connective tissue" between agencies does some important work. A particularly important example of this arose during a post-deployment observation at the WSDOT Transportation Management Center. Participants explained that they use SDOT camera feeds to catch better views of some of their own roads. Occasionally, the SDOT feeds can "see" WSDOT's highway overhead signs, and can ensure that the signs are operational and have the right text displayed, which otherwise they wouldn't be able to explicitly verify, as captured from notes taken during a Phase 1 Evaluation observation in April 2023 by another UW design team member:

> SDOT cameras
>
> - live feed on website West Seattle freeway, some blind spots that their cameras catch better Royal Brougham camera was out, others too far away, got an aerial view from Smith Tower at SDOT.
>
> - See SDOT signs in camera feed and can double check to make sure not duplicating or sharing conflicted information.

Abstracting slightly from the specific Cameleon system to the slice of data it offers (that being a live, adjustable view of three-dimensional space of much of the area's key freeways and arterials), one agency–WSDOT–could be observed trying to leverage another agency's–SDOT's–camera feeds to cover some of its own camera blind spots. This reveals a kind of system (WSDOT cameras, and data signals coming from overhead signs), and sensory (variable visibility) fragmentation of the landscape of work. The sharing of a partly overlapping system like Cameleon helps people to synthesize that fragmentation, which reinforces the degree to which that landscape of work is *shared* with other agencies. The shared "gaze" onto the roadways, and the use of other systems to triangulate internal technologies, knits or imbricates collaborative work.

6.6.2 Distal Systems

Cameleon as an exemplar demonstrates two additional aspects of embedding that are important to understanding multiorganizational infrastructure configurations. The first is the partial embeddings of what I will call "distal" systems. Distal systems are developed or operated primarily by one organization, but shared with others, usually in a somewhat limited form. The path-dependent development of the "source" system development can make it challenging to adapt to new settings: the organizational routines and procedures that drive embedded configurations, such as permissions sets, access procedures, and operating system requirements, were made for the organization of origin and its own installed bases and imbricating sociomaterial states, and don't always map easily onto the "target" organizations.

Of course, there are reasons why these target systems are instituted, despite the challenges. They provide some kind of value worth the effort on the part of both "source" and "target" organizations. This typically takes the form of access to another organization's information without the need for repeated ad hoc access requests. But this value proposition is not static. Because of each individual organization's processes of decay and new growth, a target system may no longer provide the unique value it did at the time of insertion; solved problems don't always stay solved. But it can also be, as Furstenau, et al. [51] said, a pathological "honeypot"–it provides some value, often quite cheaply and informally, so it can limp along as work infrastructure in the target organization. Further, when the system is managed by another organization, access to technical help and more generally

the tools of "design-in-use" aren't as available to as many workers as it would be in the source organization. As work infrastructure, this less clear connection to organizational decision-making and system management can inhibit the presentation of "points of infrastructure."

Yet the establishment and maintenance of distal systems also has social implications: it indicates a certain level of trust and sharing. It allows a certain level of mutual attunement. It forces at least occasional meta-interactions (those outside purely shared operational work), and provides the basis for knowledge-sharing, and comparing notes about technology approaches and vendor contracts. Both can be true at the same time, and causes the embedding and entrenchment of such systems to have complex technical and social implications.

In Figure 6.2, I sketch out a sample depiction of a simple inter-agency system sharing configuration. The upper circle is the "source" organization where the system was originally put into use. It was created with a certain user base's requirements in mind. Over time, the system undergoes the typical processes of embedding, decay, and new growth. At a certain point, organizations with some potential use for the functions or data of the system become aware of the system, often through shared operation with the source organization. Their internal systems do not fully provide the value of the system, so they create agreements with the "source" organization to be provided system access. This may take the form of a restricted login to a cloud-based system, a hard-coded link to a data feed, an actual full user install, or other forms of sharing.

In each individual target organization, this system's data and technical characteristics are incorporated. The context for which the original system was created is different at the target organizations, occasionally causing problems for smooth access or even causing the intended target organization users to avoid using the system, or forget how to access it. Because it is often the case that the target organizations also have connections to each other, their mutual access to the system may provide other ways for them to communicate with each other, and share reference material. At the same time, their individual organizations' contexts of embedding, decay, and new growth shape the individual trajectories of the system within their respective distal contexts. The "sutures" [19] showing the connection points where the target adapts the source should be made clear to users to help them address any issues that might emerge from the integrations. However, it must be done in a way that takes into account any relevant data privacy issues that can come from system data flowing freely between agencies' systems.

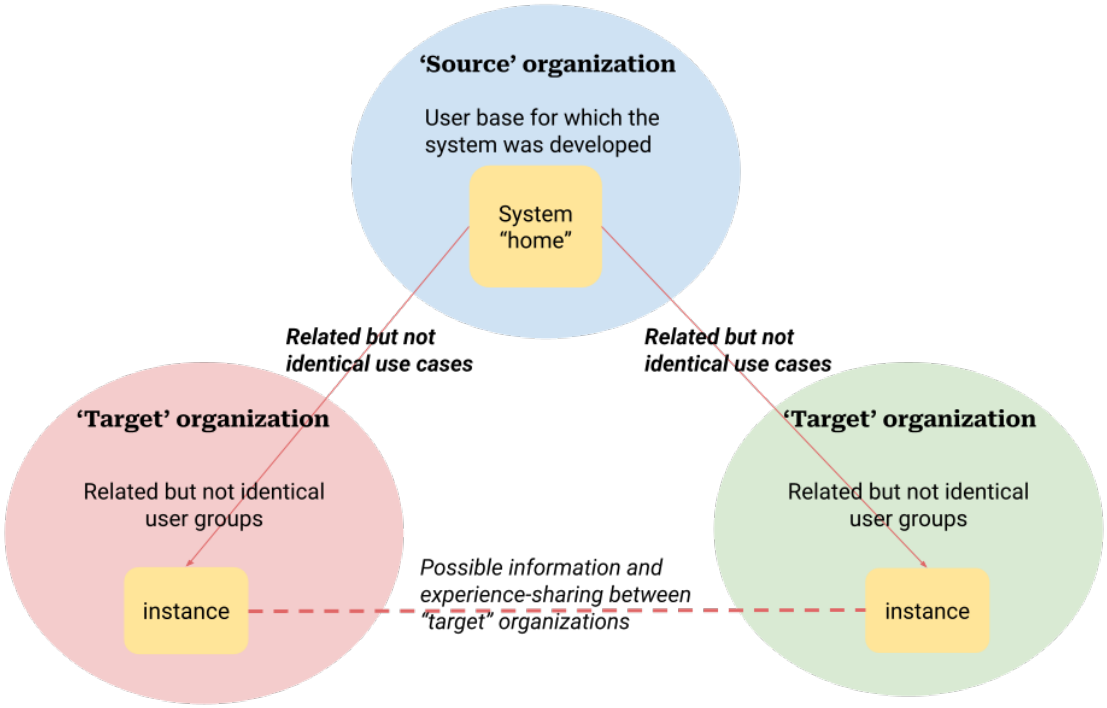

Figure 6.2: Simple depiction of a system being shared from one source organization to two target organizations

From the observations I was able to make, there did not seem to be a single cohesive strategy on the part of either SDOT IT or the target agencies' IT groups for managing the "user community" of the Cameleon system, but clearly there were some disparities and variations that limited its full uptake. Proactively investigating some of these questions in a multiorganizational design project can offer practical lessons that might make a new system development project run more smoothly.

6.6.3 Developing Shared Data Jurisdictions

The second aspect of distal system embedding is a bit more subtle, but viewed from a sociomaterial perspective, it becomes more tractable. What does the shared use of Cameleon as a distal system indicate? At a basic level, it indicates that agencies other than SDOT get sustained value from their camera footage. These agencies, with their own responsibilities and jurisdictions, see some overlap between SDOT's physical zone of responsibility and interest and their own, to the extent of setting up an often frustrating connection to a system like Cameleon. This points to not just an overlapping physical jurisdiction like sections of Interstate 5, but also a shared *data* jurisdiction. As Cameleon gets absorbed into standard procedures at some agencies and for some workgroups, these groups are sociomaterially knit or "imbricated" together, albeit imperfectly. Indeed, when there are identifiable breaks, such as the "blind spots" of WSDOT's cameras, this creates new forms of work and metawork at both source and target organizations to manage the integration. The handovers between their partly overlapping zones of responsibility become salient to system users and system maintainers. Daft and Weick have claimed that an organization is in part described by how it interprets its environment [35]. The sociotechnical imbrication of distal systems both ontologically and epistemologically changes what the "environment" even is.

6.6.4 Is the VCC a Distal System?

All of this likely raises the question: if the VCC was ensconced in histories of distal system creation and management, how does the VCC itself fit into this model? One obvious difference is that the VCC was intentionally designed to *be* an inter-agency system, rather than to have a home in one particular organization. In fact, this positioning of the VCC was one thing that made it so novel to the participating organizations. The organization-specific fittings of function and form

to histories of decay and new growth did not have the same impact on how it got deployed in the partner organizations. Partway through development, in part due to the vagaries of funding streams, WSDOT took on product ownership of the VCC. Now, updates and tech support are run through WSDOT's IT department. This creates an interesting and challenging dynamic, where WSDOT must act as a kind of vendor to the other agencies.

However, since the system wasn't developed internally to WSDOT for WSDOT's own specific needs, it creates the same support needs as an origin/distal system, without the same kind of institutional history. WSDOT's own internal embedding of the VCC also occurs in frequent dialogue to other agencies'. This dialogue often takes the form of providing updates and soliciting feedback at every-two-months SAJOG meetings, where it is common for debriefs of recent major incidents to cover what was entered into the VCC for those incidents, and when, and by whom. The lack of a singular home agency has placed more responsibility on each participating agency to express their actual desires and constraints, which has been both challenging and valuable for them.

6.7 Conclusion

In this chapter, I have taken a sociotechnical and sociomaterial approach to work infrastructure embedding in an inter-agency context. I've explored three nuanced dynamics of embedding that were uncovered by a careful observation of system use in not only many different types of work within a single organization, but operational and system connections between interdependent organizations. I additionally introduced a model of inter-organizational system embedding that helps to explain both what such embeddings offer to a multi-organizational collaboration, and why they often struggle to reach their full utility. I evaluated the VCC in terms of these dynamics, showing that while they operate over long time scales, they can in some cases begin to be observed very quickly after a system is brought into workplaces.

A project like the VCC stands in contrast to many ongoing processes of embedding. Its unusual status as an explicitly inter-organizational system that will support new forms of work can be a useful tool to interrogate and reveal challenges and opportunities for the design project, and also for the agencies themselves. Many of the ideas developed in this chapter were able to be developed because the design work of the VCC itself prompted them; the design team had to investigate the "current state" of system usage in order to know how to appropriately develop the VCC.

When developing inter-organizational collaborative systems in comparable settings, thoughtfully investigating partial access, decay and new growth, and distal embeddings can help a new system fit effectively into its many dynamic "homes." What can be a fairly conservative change in practice in one setting can be considered risky innovation in another. Especially if the design project will take place over several years, re-evaluating these ever-changing processes is also important and can change how best to socialize and integrate the system. For example, when the VCC design team learned about the WSDOT IRT's sharp pain points related to lack of WSP CAD access, we had the ability to incorporate them into our roster of high-priority users; and now the VCC is an indispensable part of their daily work.

In the next chapter, I will change my focus from the work infrastructures used in multiorganizational work contexts to the scaled entities that use, influence, and are influenced by them in different ways: the project's stakeholders.

Chapter 7

SCALED PROJECT STAKEHOLDERS AS COORDINATIVE UNITS

7.1 Introduction

In the previous chapter, I described how technology systems can become embedded within and across organizations. In this chapter, I will go into greater depth on who is using, developing, infrastructuring, and being shaped by those systems. The usual term for this is a "stakeholder." Stakeholder analysis is a common part of many major projects [18]. Stakeholders are those who directly affect or are affected by a system (or program or policy), and in software design, they are often potential users. Determining who the stakeholders are is an important exercise in defining a project's scope; because whose needs, desires, constraints, and agency and resources will influence a system helps to inform what that system will become. Value-sensitive design has added the notion of "secondary stakeholders," or those who will not directly touch the system but may be indirectly affected by its use [164]. The creation of user personas [105], a common part of Agile and Agile-style software design projects like ours (though one that has been challenged both conceptually and practically [22, 100, 124]), is also an exercise in humanizing prospective stakeholders. Despite how foundational the idea of a stakeholder is, there are still connections that need to be made between organizational/social structures in a project and all the kinds of entities who can show up meaningfully as "stakeholders."

The key idea of this chapter is to understand stakeholders in multi-organizational collaborative projects not (exclusively) as individual persons, but contextually as organizations or components of organizations interacting in a broad coordinative space. (In this chapter and elsewhere, I will frequently refer to "organizations," and when I use this term I am, unless specifically otherwise indicated, using it in the conventional sense of a formal organization such as a business or government agency.) It is useful to think of a stakeholder as a *coordinative unit*, coordinating with other stakeholders according to the practices and logics of the unit level they represent. When a new collaborative system is developed for use in the coordinative space, the project stakeholdership

expressed by these different coordinative units (or "scaled stakeholders") exerts different kinds of influence on the collaborative system, and in turn on the coordinative space that encompasses it.

This framing is intended to offer value in multi-organizational collaborative design projects more generally, since coordination, cooperation, and/or collaboration are foregrounded as primary objects of design in such projects. It can also offer value at the early stages of projects, since it implies that any relevant coordinative unit in the space can act as a stakeholder, and should be analyzed as such.

Before moving on, I will recapitulate my definitions of some key terms, as I will build upon them here:

Coordination: A collection of actions taken by two or more actors sharing a dynamic space, whether physical, virtual, or a combination of the two, to align other actions they are taking. It can occur in "real time" or asynchronously, as long as it is meaningfully time-bound. "Cooperation" and "collaboration" are types of coordination. "Cooperation" at a minimum means meaningfully taking into account the needs and goals of the other actor(s); "collaboration" at a minimum means intentionally working toward shared outputs or outcomes.

Interdependence: A causal connection between the actions of two or more actors. Deliberate coordinative actions and, particularly, the intentional planning of coordination can change the nature of an interdependence, including reducing it (such as in the design of a process that reduces duplicative effort), increasing it, or changing its morphology (such as routing a connection from one department to another).

I will next explain some important ways coordination, cooperation, and collaboration have worked in the VCC's operational context. The particularities of collaborative relationships and dynamics between and among agencies will help set the scene for the model I will elaborate later.

7.2 Inter-agency Collaborative Relationships and "Current State"

The VCC's stakeholders have worked together throughout their history of shared operation. To varying degrees, they are interdependent. None can fulfill their designated responsibilities without inputs from other agencies. For example, the departments of transportation rely on law enforcement to provide traffic control and on-scene assistance during traffic incidents; and the law enforcement agencies rely on the proper functioning of the departments of transportation to maintain safe and

usable roadways.

These past relationships and formal and informal arrangements shape both expectations for how the VCC should function as a shared system, and what feels like a safe and sensible extension of previous approaches, versus potentially risky change. It can provide resources to support imagination, but can also limit what possibilities can be perceived. In the VCC's Concept of Operations, in particular, identifying the strengths and weaknesses of the "current state" of inter-agency collaboration provided rhetorical support for the VCC project, as encapsulated by these two excerpts from the final version of the ConOps document:

> The VCC is built upon decades of agency collaboration. The mobility management agencies of the city of Seattle, King County and Washington State have a long history of working together to ensure the safe and efficient mobility of the people and vehicles of the area. This collaboration is especially strong in areas such as long-term infrastructure planning and execution, traffic incident management, and analytical and control operations for congestion management. State, City and county agencies regularly share critical system information such as pre-planned closures and construction. Traffic control centers regularly communicate by phone when incidents occur. Incidents requiring inter-agency coordination happen frequently, so a sense of community and shared responsibility has arisen over time. The VCC environment builds on these strong ties.
>
> ///
>
> Traffic managers in the region are also resource constrained and facing an ever changing landscape of demolition and construction amidst population growth and traffic congestion. Different jurisdictions have similar procedures, technologies and requirements, but some are different and naturally focused within their area of responsibility. As a result, there are limits to how well their systems automatically (where appropriate) ingest and flow data to others. These differences can cause some confusion, ignorance, or at the least, a time lag in the flow of meaningful information.

As described in the previous chapter, the agencies also have histories of sharing systems and data with each other to manage their shared work. Yet the presence of close jurisdictional overlaps

and even closely aligned incident work doesn't mean information can always readily flow between participants. Pre-VCC, for example, there was no direct connection between the WSDOT Incident Response Team (IRT) and SDOT Response Team (SRT), who did very similar work and even shared jurisdiction on a critical facility (the SR99 tunnel), as explained by an IRT participant:

> [I] inquire about how Bryan interfaces with SRT. He says they could have overlap particularly with the 99 tunnel; but there's also no direct communication with them except if they were on the same scene together. To keep up with what's going on with SRT, IRT has to call the TMC, who then has to call SDOT.

This shows that well-integrated coordinated action doesn't naturally flow from the alignment of work. This very challenge was a major impetus for the creation of SAJOG and the development of the VCC. Policies and standard operating procedures, which often structure action in ways that can give rise to such misalignments, are created over time, often in response to very specific problems rather than in reference to the holistic coordinative landscape. So it is not surprising that such inefficiencies would arise. Use of the VCC has improved some of these connections, but in the case of SRT-IRT coordination, practices are still being adjusted. The VCC and SAJOG have produced tangible benefit, but a challenge that emerged over decades won't necessarily be fixed overnight even when people want it to.

7.2.1 Service Provider Relationship

Designers must work to understand the cultural dynamics and expectations that shape the collaborations they are seeking to support. This includes some of the inefficiencies and complexities as described above, as well as broader patterns that typify relationships between participants. One important aspect of the VCC's specific coordinative and cooperative landscape is that agencies often have a *service provider* relationship to each other. If it is not unique to, it is at least highly characteristic of, this sort of public service work the agencies do, and suffuses the colleague-type relationships they also have as "partner agencies" on efforts like the VCC. While they are all regional agencies operating in the State of Washington, and at some level are connected under those higher-level structures like the Mayor or Governor, they have different jurisdictional scopes and responsibilities that aren't always linearly hierarchical. What I mean by this is that since the agencies

are not all under the same organizational structure, but are all public entities carrying out public service work they have unique responsibility for, the other agencies and operational communities are also among those to be served.

First responders in particular call out the emotional comfort and reduction in overwhelm such relationships can have, such as this Washington State Patrol trooper, who explained to me during a 2019 ridealong the value of WSP's relationship with the WSDOT Incident Response Team (IRT), who often support WSP with logistical and safety tasks as part of their overall portfolio of roadside response work:

> When Lee joined [WSP], IRT was a fledgling group, but they've gradually come to work more hand in glove with WSP. Now, with IRT handling more of those types of tasks, WSP can concentrate more on the policing aspect of their job and can be more proactive. Importantly, it lowered the stress level for troopers since it allowed them to concentrate and be less overwhelmed, which helps with both job performance and retention. And Lee enjoys interacting with IRT and talking shop with them; there's enough overlap that they can really connect and bond.

During my 2025 interviews, during the incident scenario discussion, a Seattle Police leader (P8) described a key on-scene responsibility of SPD being to set up traffic control to allow the Seattle Fire Department to undertake their work (in this specific discussion, a hypothetical hazmat situation):

> I assume if [the potential material being leaked from the commercial vehicle involved is] gaseous, and we don't know where it is, we might have to evac either to adjacent buildings or to traffic stopped on I5 to get them out of a danger zone, and set up traffic control to assist in getting vehicles off I5–clearing the way so emergency vehicles can get SFD in, as a hazmat agency. They have a large equipment response, and it would be hard to get them through stopped traffic. And again, I'd be monitoring to see what was going on, doing notifications through my chain of command and eventually mayor's office and SDOT, but the SPOC [an SPD operations center], identifying how we can get more resources to see what's necessary.

This comment emphasizes P8's turning of some of his own situational awareness and communications efforts to supporting the work of the Fire department, even pulling in additional Police resources if needed.

These are only a few examples of this sort of relationship. Police assist King County Metro personnel by providing traffic control for a disabled bus; and King County Metro personnel rapidly repurpose buses as warming shelters for incident victims if the Fire department is handling a major incident during cold or rain. The departments of transportation use their control centers to improve traffic flow on the roadways for the public more generally, but during incidents, they emphasize the importance of helping their partner agencies get to the scene more efficiently and safely.

This even translated to attitudes toward SAJOG participation: personnel from Seattle Fire (SFD), for example, often styled themselves more as providers of data–the critically important SFD CAD feed–rather than active beneficiaries of the VCC's data or processes. One SFD chief confided that while they dutifully attended SAJOG meetings, they thought their internal processes were in ideal lockstep with their systems, and the VCC wasn't expected to significantly improve their operations (personal correspondence, 2025). This can be positive because it can lead to altruistic, generous participation in the multiorganization, but it can also limit the ability of participants to see possible improvements in their own work process process that can come from learning about the work of their "customers."

These aren't only basic facts of interaction, but important culturally; the agencies are cognizant of this service provider relationship, and often characterize their relationships with other agencies along these lines. Concepts from infrastructure studies can help us understand why. Because each of these agencies is a different kind of infrastructure manager, what is transparent, supportive infrastructure for one is actively managed *structure* for others. The clearest example of this is the roads, which are managed by some agencies but used for transport by all. The very nature of this division of responsibilities contributes to this inter-organizational dynamic, which must be understood when designing for it.

7.2.2 Negative Coordination

However, there is another side to this relationship structure. Because each agency has its own jurisdiction and responsibilities, which can occasionally be at odds or have some kind of disciplinary scope over other agencies, *negative* coordination forms a part of this landscape. Recall the definition of coordination I am using for this dissertation: "A collection of actions taken by two or more actors sharing a dynamic space, whether physical, virtual, or a combination of the two to align other actions they are taking. It can occur in 'real time' or asynchronously, as long as it is meaningfully time-bound." This alignment of actions doesn't need to be mutually beneficial, or socially positive.

Negative or antagonistic coordination in the context of this work consists of those instances of coordination that are still part of the portfolio of work people do, but that have an emotionally negative or structurally antagonistic character. To be clear, negative coordination is not *every* unpleasant interaction between people in a coordinative space; it is specifically an instance of coordination–time bound, aligning other actions, and often supported by standard operating procedures or coordination systems. This can include using documentation and systems to establish fault or responsibility, and seek financial remuneration (such as if a first response vehicle strikes a piece of infrastructure). It can also mean finding ways to align tasks even in light of cross purposes; actors may have a broad shared goal in a *global* sense–the safe, efficient functioning of the regional transportation system–but particular tasks or assignments that conflict during in-the-moment, on scene work. Malone and Crowston, as noted in the literature review, claim that some level of goal conflict is quite common in complex coordination situations and can even be an engine of innovation [98]. So the need for negative coordination to handle such conflicts should also be expected in the complex work of regional transportation management.

This can occur when different types of work that intersect have different, even sometimes incompatible, goals, with it being left to individual workers to seek resolution. During a Use, Feedback, Refine (UFR) ridealong with a WSDOT Incident Response Team (IRT) driver, I learned about the practical difficulties of assisting King County Metro vehicles when they are stopped on the freeway:

> [He] jokingly says that "Metro are my arch nemesis." Meaning, his goal is so much to use whatever means necessary to get traffic flowing again, while the driver is in a workflow that's much more dependent on information and approvals from others. So

> if there's a stopped bus and he talks to the driver about what's going on, they often don't know when a supervisor will arrive, just that they're on their way; and needs explicit approval before moving the stalled bus. When the supervisor does arrive, they in turn don't always know when a mechanic will arrive. So their workflows, approvals, and objectives are just so different that it can be frustrating.

And at times, it can mean fault-finding and cost recovery, as explained by a post-deployment evaluation interview with a WSDOT IRT driver:

> [G]athering data to create a cost recovery event later on the road. If we know there's a party responsible, we'll track our charges and time, then forward that to the DOT and they can decide if they want to charge people. [asked about how often that happens.] It varies, but usually there's some person who bears some culpability. But we (IRT) don't make that judgment, we just send the information to the DOT and they make the decision.

The SDOT Response Team (SRT), meanwhile, has a slightly more complex relationship with the Seattle Police Department than IRT has with the Washington State Patrol, in part because of the different "paper trail" that emerges from them interacting with each other, as discovered during UFR4:

> While SRT has to be very cautious about contacting SPD directly, the SRT drivers sometimes do get direct calls/requests from officers. This triggers a paperwork process; any request from SPD for their work has to get logged because it generates a work order, which governs their labor.

In the first excerpt, the negative aspects of coordination are compartmentalized as something that happens after the participant's activities are over. In the other, the prospect of negative coordination causes people to change how they interact with people from other agencies. Part of the general coordinative landscape, then, is how people understand and respond to the potential for negative coordination.

The work of developing the VCC was also part of the work of fostering the development of its collaborative community. That is, the operational stakeholders of the VCC work together in

countless ways, but a sense of community identity and an understanding of shared purpose require deliberate tending and development. Before the VCC project formally started, the antecedents of SAJOG and the UW design team started meeting under the expectation that a useful shared system for traffic incident and congestion management would support that sense of community. This meant learning from and with that community to enrich the capture and use of data generated through coordination. However, the ability of the system to enable shared work, and the evaluation of that work, could also potentially further the ability to "improve" or add data to negative or antagonistic coordination, as it could provide further data to support chargebacks or establish blame. This could theoretically present challenges to fostering a harmonious community. While neither the design team and operational stakeholders dwelt on this possibility much in project work, it was something on the minds of at least some participants. For example, in a 2025 interview, a Seattle Police interviewee described the social complexities of after-action reporting during our discussion of the example incident scenario:

> Ridley: What kinds of analysis and reporting would SPD do once this incident was over?
>
> P8: The SPD protocol for a large incident like this would be to have the commander do an AAR, after action report. I'm supposing that in the instance of a unified command, multi agency situation, that there'd be a large multi agency debrief. Perhaps individual agencies do theirs first, then a large one afterward. Because agencies tend to be protective of themselves, and not necessarily admit fault, they don't want a new cause for embarrassment. But if you've identified mistakes, bringing them out to talk about them so they don't happen in the future, there's always the question of liability in these things, so there's a need for caution about how that's done.

What I want to call attention to here is the prospect of negative coordination can affect how people view and participate in data journeys and their inputs because the data could eventually be used to support negative coordination. This means that sometimes collecting more data is instrumentally useful but not supportive of social harmony.

Negative coordination is not just something that happens in the heat of the moment, but something with agreements and structures in place to support it. I distinguish it from general

"conflict" in that it has to do with fitting shared inter-organizational needs to organization-specific needs. It's not inherently personal (though of course it can become so), and the participating entities aren't in inherent competition with each other. Rather, they have different ways of doing their work with different priorities, and pursuing one's goals can occasionally have negative impacts on others. The notion of negative coordination is similar to, but different from, "contested collaboration" as developed by Sonnenwald and Pierce [145], who also studied urgent work situations such as military operations. In situations of contested collaboration, "team members may appear to maintain an outward stance of cooperation but strive to advance their own particular interests or information claims." Participants in an observed battlefield exercise appeared to lack an "interwoven situational awareness" or an appreciation of how their own actions would negatively impact others, leading to unnecessarily wasteful actions and even the loss of life [145]. Negative coordination, instead, often falls out from smaller-scale incompatibilities in tasks, or hard-to-avoid missteps such as property damage, in a situation with broadly *compatible* global goals. It is also something that can, as a consequence of how I have delineated the "three Cs," be *cooperative* in its own way, since negotiating and planning it effectively draws on knowledge of others' needs and constraints.

I do not wish to overstate the importance of negative coordination–within the context of the VCC project, negative and antagonistic coordination represented a fairly small proportion of coordinative actions and routines, and the story of the VCC was not about attempting diplomacy between adversaries. I bring attention to it because it is a structural possibility for interaction that can shape interaction and relationships, and practices of data retention and analysis. Finally, it is something that can be more and less *visible* and salient in design, not just based on its factual importance, but on how participants are conceiving of the nature of their coordinative relationships–another way both the levels and types of interdependence in a coordinative relationship can be "socially constructed" [42]. This is a point I will return to shortly.

7.3 Stakeholders as Coordinative Units

So far, I have outlined some characteristic dynamics of collaboration in the VCC's operational community. Some of these dynamics highlight ways individual people connect with each other, with their domain peers, and with agencies. However, that is only part of the story. Critical to understanding the dynamics of the VCC project is also to recognize that there are different scales

of entities that are simultaneously acting as "stakeholders" of the project's design space in different ways. Coordination is expressed differently at different levels, or along different axes of action: relational, domain/task-based, or organizational.

The term "scale" makes many appearances in this dissertation, so before moving on, I will clarify what I mean by this term. Scale and scaling are issues of concern to CSCW and HCI; as an entity's scale grows, it faces challenges around making sense of and appropriately controlling its operations, prompting the need for more effective CSCW technologies [122]. Organizations also seek to understand and manage their own scale, giving rise to what Ribes [120] calls "scalar devices." Even what counts as "large scale" or "small scale" depends on the frame of reference. It can be determined by the amount of work output, the jurisdiction, or more typically the number of teams or persons it contains, such as Tendedez, et al.'s categorization of an organization with 10 or more software development teams as being "very large" [151]. Yet in other work, multi-institutional collaborations viewed from the perspective of large cyberinfrastructure studies may only count as medium sized [113]. When I speak of "scaled" stakeholders, I am using "scale" in the sense that a stakeholder has an identifiable structure, commitments, and constraints by virtue of being composed of not only individuals but supporting structures–such as, but not limited to, charters or written policies–that scaffold its persistent identity. A scaled stakeholder contains smaller scales within it or as meaningful parts of it, with the smallest scale being an individual person. I do not refer to numerical size guidelines to identify differences in scale, but rather structural distinctions, with numerical size occasionally being significant enough on its own to create structural distinctions and particular "stakes" (for example, an agency in a coordinative space that is so large that 80% of the members of that space work for that one agency, will exert itself differently and more strongly than other agencies in the space, even if they are otherwise structured similarly).

7.3.1 Perceptions of Organizations as Gestalt Actors

Individuals in the VCC project, as in any project, have their own goals and desires, and their own individual relationships with other people. But they also frequently conceived of other agencies as gestalts, and characterized the supposed personalities, goals, or typical challenges of those agencies when explaining how they expected collaboration to work in the VCC project (as a shared project

they were working on together to achieve a shared regional collaborative outcome) and in the use of the VCC (as a coordinative system to be used for operational work).

For example, in a UFR4 (Use, Feedback Refine) workplace observation, a WSDOT TMC worker described to me how he interacted with several other agencies, and with different levels of immediacy, particularly when there are issues with the State Road 99 tunnel (over which jurisdiction is shared between the city and state).

> [Arvand explaining] Contact with SPD primarily concerns the 99 tunnel, and the tunnel is a major source of contact with SDOT as well. Unlike with WSP, whom they have on speed dial, "they" [the nebulous "powers that be"] decided the TMC must call 911 to get in contact with SPD, rather than having a direct line. Response times with SPD can vary more than with WSP, and that it can be hard to know what to expect (they also have less information about who and when responders are actually dispatched).

These characterizations often express both frustration with other agencies and sympathy for the challenges they seem to experience. At a 2019 ConOps meeting, an SDOT leader who had become involved in the ConOps process considered why other agencies might be reluctant to fully engage with the VCC and SAJOG even if it might ultimately benefit them:

> With SFD: Fire dept is undersourced. City is growing so fast they don't have money to build new fire stations. ...
>
> They're beleaguered. Don't have resources to cover Seattle's growth. They have a union that really constrains what they can do. Constrained barely meeting ends. There are entities within the city that feel sorry for themselves. Police have a union too and also in penalty box [due to oversight regulations in place at the time]. Now they are being asked to do this SAJOG thing.

From their experiences working with other agencies in the past, people also made predictions about what value they expected other agencies to derive from the VCC. At another ConOps meeting in 2019, people predicted what kinds of value different agencies might reap from the future VCC, based on both their operational needs and the current state of their work infrastructures.

(Note: The below text is from a set of informal meeting notes where individual speakers were not consistently recorded, so the statements cannot be individually attributed; but the meeting participants included five UW participants, a Pariveda representative, and an operational stakeholder from the Seattle mayor's office. From context, I believe most of these statements were made by the participant from the mayor's office, but I am not certain):

> –Asked SDOT, what would you really like to see? Want this to be a primary tool. SDOT legacy tools are out of date
>
> –KC Metro wants to be told where their buses should go
>
> –Incident responders- we need to get them interested because they are the data providers. The IR might need to know the best route to get to an incident and they can get that from the VCC.
>
> –WSDOT wants a solution that alleviates stress on major corridors Different agencies have different ideas about what they want out of the VCC
>
> –In terms of CM [congestion management], Fana and SDOT has the most challenges (why they would like day-to-day use)

As part of the UW design team, I had only partial access to the social dynamics and strategic discussions happening at different agencies and workgroups. Further, because some agencies participated more directly and consistently in the VCC development than others (especially WSDOT), we developed more candid relationships with some people at those agencies. In this way, the boundary or "interface" of the different organizational configurations present in the project affected how well we could actually model and treat these dynamics. Functionally, the participating agencies made decisions about how we could perceive them. In this way, we the design team also occasionally had to interact with the agencies as gestalts, and this had a direct impact on our ability to identify potential elements of the VCC and develop them with confidence that the entire community would find them useful.

7.3.2 Forms of Coordination at Different Scales

In the VCC's context of inter-agency traffic incident management work, coordination between individuals often takes different forms from coordination between individuals and agencies. The analysis here differs from, for example, Paine and Lee's Coordinative Entities framework [113] in that it is not focused on typifying forms of organizing in collaboratories. It is more aimed at understanding how to make sense of how inputs, needs, actions, and constraints differ between different scales of stakeholders, and how that might be mapped onto specific design efforts. It allows us to ask questions about how, in a given coordinative space, each unit coordinates with others at its own level, with nested internal units, and with external units at other levels. Interaction between agencies (*qua* agencies) is often slower and aimed at more structural factors; it is the metawork that guides the articulation work of direct operations [58]. Individuals of course carry this coordinative work out, but they consciously do so under the auspices of their organization: taking on the needs and risk sensitivities of that organization, and guided in their decision-making by the organization's own directives and policies.

A process like policy document approval, which happened frequently in the VCC project and in similar projects, also moves through intra-agency processes and review-by-committee. So, to partners external to an agency, it comes to resemble individual activity less and less. Data-sharing agreements, reviews of ConOps drafts, and analyses of potential data security risks often followed this pattern. Documents would pass beyond the organizational "membrane" we on the design team, and operational stakeholders in other agencies, could view; then be pushed back out of it into the inter-organizational collaboration space some time later, annotated with additional requirements and constraints.

The individual/organizational stakeholder distinction is not the only relevant one. What were often called the "operational communities" of the VCC also had their own ways of coordinating. These were subcommunities oriented around a specific type of work, such as public information officers. These operational communities (which I sometimes call "workgroups" in this chapter for brevity) interact beyond the boundaries of their own organization, and to varying degrees, have a sense of shared identity and culture.

One example of such a workgroup in the VCC is the public information officers (PIOs) who

work at the various agencies. People in this workgroup typically are responsible for public communications on behalf of their organization: social media posts, blogs, press briefings, informing executives about emerging incidents, and other outward-facing tasks and strategies. Several PIOs had even, prior to the VCC's development, made some efforts toward creating a regional concept of operations (ConOps) for themselves. While this document was not completed and incorporated into the PIOs' work, the impulse to create a ConOps spoke to an interest in determining how similar or different the PIOs at each agency operated, and bounding that where appropriate. A Concept of Operations or similar guiding document has a peculiar place in such an operational subcommunity. It must be relatively light on formal responsibilities and expectations, since the work of PIOs is formally controlled by their own agencies. Instead, it can establish techniques and common expectations for information-sharing practices within organizational constraints. For example, PIOs can specify under what general conditions a message created within one agency should be shared by another; or how often PIOs should hold conference calls during major incidents. To make communication clearer and more consistent, they can create shared terminology and tactics (which has pitfalls when expanding beyond such workgroups, as I will discuss in Chapter 8). Cultural norms can also present obstacles to the use of a collaborative system: for example, early project work (pre-VCC development) yielded the insight that for many area PIOs, cultivating one's own "Rolodex" of contacts was a personal accomplishment, and reflected one's expertise regarding the regional transportation and emergency management community. A new system that made all of those contact points easily available to any user might compromise that sense of accomplishment and satisfaction.

The unique forms of coordination, cooperation, and collaboration I want to highlight with this type of stakeholder are about identifying patterns of work that hold between organizations. This is different from organization-to-organization coordination because it is typically less top down; less about formal agreements between agencies and more about skill sharing and norm building. Disciplinary and industry trends are also more directly relevant. It is different from person-to-person coordination because it is more structured, abstract, and topic-specific. It has a more defined professional community, at least in the regional multiorganization I studied. People can also move in similar roles *between* organizations, bringing inside knowledge and contacts from their past organization into the new one. Thus, this type of coordinative unit operates in some ways

orthogonally to organization-to-organization coordination, and can exert influence by shaping work culture and allowing individuals to move between organizations. Thus, this kind of coordinative unit's "stake" in a new inter-organizational collaborative system is how *categories* of work are represented and undertaken, and what counts as professional and effective work in a particular category.

I do not want to imply that these are totally distinct categories. In the context of inter-organizational collaborative work, the individuals who tactically work in real time with members of other agencies do have to juggle their multiple affiliations and identities and constraints, including acting as representatives of their organization. But the focus during person-person coordination is on getting the real-time work done with a colleague who may or may not be from a different organization. The on-the-ground work itself is most salient, and anyone who is sharing in it is a potential partner–or obstacle, in the case of negative coordination. Organizational policies and procedures govern the actions of individuals, and can subject them to discipline after incidents, but the in-the-moment calculations of coordinated actions means the specific interactions aren't fully predictable. The important distinction between plans and situated action predicts that this will inevitably happen; "every course of action depends in essential ways on its material and social circumstances" and intelligent action is about adjusting the enactment of plans to those critical circumstances [149]. In this case, that distinction mirrors the different coordinative relationships between the units. When people from many organizations are participating in a coordinated action, structures like incident command stations on major incidents can serve to stabilize this potential variation.

Organization-scale Stakeholders Managing Individual Stakeholders

Looking at how different scales of stakeholders relate to each other can help to begin unpacking the practical and conceptual problems of developing a useful collaborative system. An agency, acting as an organizational stakeholder, must consider how its different types of workers must relate to the inter-organizational coordinative context. It must decide how to position those different types of workers, for whom it has *internal* structures of trust and authority, with respect to any inter-organizational collaboration.

The VCC's partner agencies typically are hierarchical and rule bound, both due to organizational culture and history, and by necessity in their position as democratically accountable public agencies. Their internal "trust model" with respect to a given worker–what the worker is given implicit and explicit trust to do on their own volition, how high quality the information they provide is, and how much or little surveillance they are subjected to–is different from the external/collaborative "trust model." The collaborative work is necessarily distinct from entirely internal work, requiring sharing of resources and time (and sometimes, shared systems like the VCC). An organization's internal terminology, tacit knowledge, and insider information are at least partly reduced in a shared working environment, and the time-sensitive and urgent-emergent nature of the work means that establishing complete clarity is not always feasible. Therefore, organizations must take into account how each individual participant creates risk and liability with their individual participation in collaborative work. A system that allows users to see data streams they couldn't before, or serve as a vetted source of truth to a wider audience (who often have less context about how they operate), can create as many risks as it does opportunities.

For example, during the VCC's development, it became more obvious from our workplace observations just how integral to successful incident and congestion management the roadside assistance workers (WSDOT's Incident Response Team and SDOT's Response Team) were. Moreover, operators at the departments of transportation's control rooms who were asked about how information sources were vetted during an incident, and what was considered most credible for decision-making, often listed reports from SRT and IRT as very high quality (i.e., most likely to be accurate and actionable). SRT and IRT operators were also asked to take on-scene pictures and save them to shared spaces (such as network drives or Teams channels) both for decision-making during incidents and for reporting afterward.

On-scene workers responsible for taking physical actions at the incident were not only doing critical and skilled on-scene tasks, but were also acknowledged as uniquely valuable sources of important incident information. In many cases, they could even supersede VCC information, as explained to me in a 2025 interview by a King County Metro leader. The service quality supervisors, who play a similar role to IRT/SRT at KCM in terms of providing urgent service to buses, have the "highest level of trust" for KCM, although their focused on-the-ground actions can limit their ability to view the "big picture" of an incident:

> P2: There are times when, you know, the VCC disagrees, or SDOT has a pretty good camera network at this point, and we can watch and we can, you know, we can look at those cameras and see what's going on. So the highest level of trust is in a Service quality supervisor on scene. But we do look at multiple sources. Usually we rely on them once they get there, but they, they don't always get the big picture being on scene, especially for a large incident.

However, it was also common for leaders or managers at these agencies to deliberately limit the permissions of IRT and SRT drivers in the VCC. For example, an IRT leader interviewed during Phase 2 of the VCC's post-deployment evaluation period said that

> Some people want IRT to be able to put information in, which can be a hindrance. Not everyone knows how to enter info professionally. It's just as easy to call the TMC and let them put information in VCC; they can be a filter to ensure information is presented correctly and professionally.

A similar sentiment was echoed by SDOT managers with respect to SRT drivers, though they did express that drivers should be able to create Notes in the VCC and update pictures; but that exactly how SRT fit within the current VCC workflow was still uncertain.

In short, on-scene workers' unfiltered participation in incident work was of high value and quality within their own agency, but they weren't universally seen as trusted participants in inter-agency incident work, empowered to convey this information on their own. So, rather than being able to directly document the important information they're perceiving in the VCC, they might be requested to radio in to a traffic control center, and the control center operator might take that information and input it into the VCC on their behalf.

Data in a collaborative system has a provenance not only from agency-internal systems, but also from particular people in particular roles; and organizations sometimes limit shared utility in preference to internal control. They therefore seek to exert their stakeholdership by maintaining adequate security, control, and reputation.

By the same token, some managers in the VCC project saw the new tasks associated with the VCC as something they needed to *protect* their subordinates from. This was a concern in several interviews during the VCC's evaluation period, including a manager at King County Metro:

> VCC more useful to KCM's coordinators, though it's a really stressful job, and introducing a new technology increases that stress.... A lot is changing at KCM now: all new policies & procedures, new technologies. There's so much change and they can only push people so hard.

An SPD captain:

> During a huge major incident, some people would use VCC if they could, but there's an incredible amount of mandated training and related things, so taking it seriously would be an additional burden. So it might have to come down to a rule that if an incident is significant enough, people have to use it.

And an IRT manager:

> He doesn't oppose drivers sending pictures in (such as to the TMC), as long as the scene is secured enough that taking a picture isn't taking them away from their regular duties. But people often ask for pictures, so we want to carefully guard the expectations we have of on scene personnel sharing images. It can be a distraction from their normal work.

As seen from these excerpts, concerns emerged about VCC participation as it might 1. Detract from users' key responsibilities (even if it provides value for inter-agency collaboration); and/or 2. Cause them fear and anxiety as their actions became visible to the somewhat intimidating range of VCC users. These concerns found expression in the ways agencies allocated VCC user roles and permissions to their users, as each agency was permitted to assign roles to its own users as it saw fit. There are good reasons for these organizations to make these choices, but they can have consequences for how discoverable the putatively shared data they produce eventually becomes. As the shared practices of coordination and data-sharing also change through VCC usage, however, these calculations aren't necessarily static, and part of the work of designing-in-use is re-investigating the value proposition offered by different types of participation.

7.3.3 Modeling Multi-Scaled Stakeholders in an Imbricating Collaboration Space

Now that I have analyzed some of the ways different scales of stakeholders expressed their needs and constraints in the VCC project, I present a somewhat more general model. When applied outside the domain of traffic incident management, the unique forms and cultural histories (such as a service provider relationship) will be different. But understanding them in their particulars, in terms of different coordinative units interacting with each other, can give a more thorough understanding of the coordinative space: its structures, its dynamics and influences, and its possible futures. The diagram in 7.1 depicts in simplified form how different scaled coordinative units interact in a coordinative space, and how that translates to their stakeholdership in a new collaborative system. The diagram shows a green bubble as an organization, with a highly simplified internal hierarchy: one functional workgroup whose membership extends outside the organization, and one human in that workgrou. It shows how an organization interacts with another organization (the lighter green bubble), how individuals interact with that other organization, how workgroups or subcommunities of practice (such as, in the VCC's example, public information officers) interact with each other, and how individual people interact on-the-ground or in-real-time. In the diagram, the organization, workgroup, and individuals on the right are not depicted in a nested way; this is only for visual clarity and to focus on one type of coordination at a time.

The large gray area in the background is the general inter-organizational coordination space; the context of coordinated work, similar to a "common field of work" [131], but more fluid in its repertoire of tasks, jurisdictional boundaries, and potential participants. A new collaborative system is a component of that space, and its process of development, introduction, and continued use also affect the shape and size of the space in different ways. Dotted lines from workgroups, individuals, and the organization to the collaborative system show how these coordinative units can behave as stakeholders in the system and through its development process.

Each of these forms of coordination, at different levels, represents different ways of being a "stakeholder" in the development of a new collaborative system. A public service organization or agency has a stake in maintaining its jurisdiction and scope of responsibility, upholding its reputation, avoiding unnecessary increases in risk that accompany new forms of coordination, managing its people and holding them accountable, and so on. It can stand to benefit from improved interac-

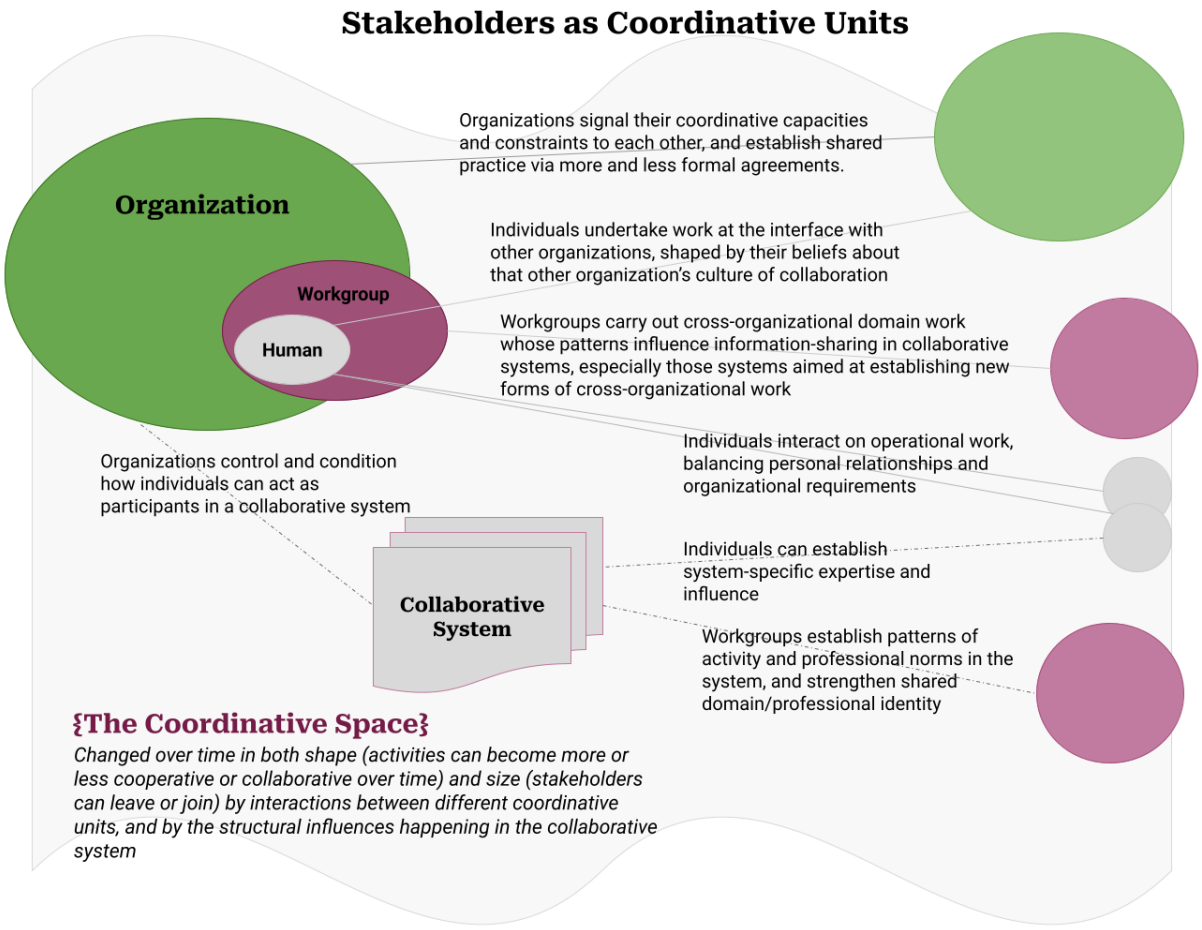

Figure 7.1: Depiction of coordinative units at different scales interacting in a coordinative space, with a collaborative system being one dynamic component of that space

tion, but it can also lose leadership positions, or expose itself to uncertainty around regulation and liability. A workgroup has a stake in maintaining its working norms and relationships across the coordinative space (both within and between organizations), and may shape how this is expressed in interfaces and terminology in a collaborative system. An individual, meanwhile, behaves as one would expect a traditional "stakeholder" to do, including their personal relationships, reputations, and career opportunities. A collaborative system design project provides a structured space to shape the conduits of coordination and information-sharing represented in the collaborative system.

When the new collaborative system is introduced to the coordinative space, organizations express their stakes in part by how they structure the way their own people can act as *individual* stakeholders in the system. They will also constrain data-sharing regulations (such as how data are stored and disseminated after incidents are completed), how user roles are structured (e.g., whether individual agencies' users are allowed to have administrator-level permissions in the system, and what limitations are placed on such roles), and which kinds of workers are allowed to access and use specific shared data, and the like. All of these higher-level concerns affect the specific interfaces, data pipelines, and structures of the system. Individual participation is also conditioned partly by the organization-level dynamics happening in the coordinative space. Since in the case of the VCC project, the VCC was also the first truly shared system these agencies used for traffic incident management work (as opposed to more limited distal systems as discussed in chapter 6), it was an opportunity to set new collaborative patterns, and to subject aspects of the coordinative space to explicit analysis and reconsideration.

Influence of VCC on its Coordinative Space

The patterns of usage the VCC supports or suppresses subtly shifted some inter-organizational collaborative processes. For example, a 2025 WSDOT interviewee (P15) explained how the VCC shifted the process for passing along questions from the public to the relevant agency, allowing both a more direct way of conveying information to the public and avoiding pestering the agency that owns that information with "remedial" questions:

> You know, my thing was always like, if someone calls SDOT or SPD, because this happened all the time with me at dispatch. They called in and be like, Okay, well, we're

> not actually handling that. And so you would have to call SPD. So let me get you over to SPD... If SPD is handling something or State Patrol is handling, they're often, if it's a big incident, they're often busy. They don't need these remedial questions... So having the VCC, and having that public information that can go out and already being vetted, someone else that isn't handling the incident like, well, it looks like State Patrol's last update was blah blah blah blah. Or it looks like, WSDOT put out an update That was this. And so oftentimes those questions from the public can be handled, even though you're not the agency handling it. If you have the information, which is the point of the VCC, then you can tell the public that information.

Here is an example of where the effort to orchestrate and work through using the VCC was, at least subjectively, worth the effort at a community level.

Collaborative dynamics and beliefs about what others would find useful also shaped the system. Like several other users, a WSDOT user interviewed during the 2023 VCC evaluation period explained how he had repurposed the incident model (a collaborative page meant for shared management of major traffic incidents; refer back to Section 3.3.1 for more details) to notify other VCC users about "flammable cargo restrictions" (temporary restrictions on what types of cargo can be carried on parts of the roadway, often due to construction):

> [He] has been launching VCC incidents for "flammable cargo restrictions." This allows other within his agencies and anyone using the VCC that there's a restriction. Even if we post this info in other places, it's nice to have it in the VCC so everyone can see it.

This can be seen as a form of design-in-use, but a specific form done in reference not to one's own needs or one's own agency's direct needs, but in reference to what the user thinks other agencies will find useful. This user was indeed correct, as in 2025, the VCC was updated to add a section of the site specific to planned events.

New responsibilities people were given, or chose for themselves, put them into a new collaborative configuration with respect to the VCC, one that didn't strictly conform with their general job descriptions. Using the VCC even, in some cases, had an impact on individuals' intra-agency jobs. Multiple people who were particularly interested in the VCC and became "super-users" used their

experience with it to make changes to their intra-agency job description (such as a PIO who moved to a VCC advocate position within their agency). These individual-level changes moved around work and expertise, thereby subtly shifting the general coordinative space as well.

As defined earlier, collaboration is a subset of coordination that involves some level of shared outcome or output between the actors. But importantly, the situated meanings of the *shared* outcomes are different for each agency, person, and operational community who participate in them. A new collaborative system being created means that there was a shared outcome (the availability of the system), but if that system becomes core work infrastructure for one organization but more peripheral for another, the actual sociomaterial trajectory of the collaboration is different in the two settings.

Stakeholder coordinative units further face different constraints, costs, and tradeoffs at different scales, and gain different forms of benefit from the shared efforts of collaboration. For example, a change that creates new career opportunities can mean a new lifestyle and coworkers for individuals, but possible loss of a valuable employee for their organization and the organization's capacity to carry out certain kinds of work. For another example, a shift in the coordinative space to emphasize some activities over others brings the workgroups undertaking those activities to the fore as leaders who can exert greater influence going forward. All of this means that designing a new collaborative system means making decisions that will selectively visibilize different aspects of scaled coordination. It also gives those participating in design–operational stakeholders and designers–the opportunity to enable different touchpoints between scales of coordination, which can allow information and influence to flow between them in different ways.

In terms of work infrastructure, reconfiguring how people work with others outside their organization can change the scope of what they consider their goals and assigned tasks to be. In that sense, work infrastructure in inter-organizational work contexts can also be referential, to the extent that awareness of external partners' systems and constraints influences one's own work and use of systems. Pipek and Wulf comment that infrastructure can be "in the eye of the beholder" [117], and this referential quality arising from interchange between units in different organizations can be one way stakeholder's infrastructural "gaze" can shift.

7.4 Design Challenges with Scaled Stakeholders

The previous sections likely raise questions about how such a lens on what a design stakeholder is allows us to understand the design dynamics of a project like the VCC. If a stakeholder can be reframed as a coordinative unit in an imbricating collaborative space, then if we look for units of coordination, we should expect to find the kinds of meaningful needs and constraints exhibited by stakeholders. We can then unpack the expressions of agency that influence a project, and clarify some of the apparent tensions and contradictions that emerge when different scaled stakeholders coordinate.

7.4.1 Codesigning the Collaboration

Many of our stakeholders at all scales had different ideas of what "collaboration" was, how much of it was desirable in the VCC, and what that should look like at both the project management and interface levels. Supporting collaborative work was a functional VCC goal, but participating in its creation and adopting it was also meant to improve the state and *quality* of inter-agency collaboration overall. All of this meant that the design team had work carefully with operational stakeholders to model what "collaboration" functionally meant in the VCC system. Collaboration is a large and abstract idea–the relatively small slice of literature I have presented on the topic is testament to that. Connecting that abstract idea to tangible design elements means trying to unpack what collaboration involves and how it functions for each type of stakeholder, and how that can be reshaped by the many kinds of collaborative interactions they have.

The UW and Pariveda design team worked to develop and foster our own working definitions of what "collaboration" actually meant in the project. Some of these working definitions implicitly invoked scaled stakeholders, even though the actual design instruments we used (such as user personas) remained constrained by the individual-as-stakeholder framing. As is often the case, such an important concept as "collaboration" remained nascent and contested even as we were designing for it. For example, consider the following design-team-internal document, excerpted below. This document was the outline of an epic for ingesting new data into the VCC. Epics are conceptually related collections of user stories/tasks in Agile design. In autumn 2021, the senior Pariveda design team member led the design team in planning several major arcs of work, which

included numerous epics. The below was part of the planning document for the epic called Ingesting New Data, which had to do with bringing in data integrations beyond the original four Integrated Dispatch Feed CAD sources, such as current traffic conditions to be included on the Situation Map.

> Collaboration among agencies is when decisions and planning occur with 2+ agencies involved, so the resulting decisions and plans are (presumably) better than if made independently. VCC Incidents are major incidents where collaboration is vital for acceptable incident and congestion management.
>
> Note: get specific with 2+ agencies – role of LE+DOT, e.g. SPD + SDOT – is that a big deal? SDOT + WSP – is that a big deal?
>
> The primary feature for collaboration is TBD {Q: Can we say the result of collaboration is shown on the Incident Model, but the process of collaboration occurs elsewhere? For example, PIO collaboration may occur in the VCC (as a feature), but on scene collaboration occurs outside the VCC (and we need to get the results into the VCC)

This excerpt displays some initial attempts to "design" the collaboration by identifying a working definition for collaboration that can be designed against (prompting a question about boundary conditions and what particular interactions are "a big deal") and where it happens (e.g. the "result" of the collaboration is on the Incident Model but collaboration itself occurs elsewhere). Abstract conceptual questions about the nature of collaboration were necessarily connected to specific questions about creating features that would support a particular model of collaboration.

Another, even more granular example arose later in the design process. As an iteration on the Integrated Dispatch Feed, we created a new feature to the Integrated Dispatch Feed where people could pin any specific dispatch feed records they wanted to individually watch, which would keep them in the top of the Feed for easy access. Simultaneously, any dispatch events pinned by any users would be added to a list of "Noteworthy" dispatches, which *all* users can see. In Figure 7.2, there is a yellow circle where "pinned" dispatches would appear if the user pinned them. If a user selects the "Noteworthy" view instead of "All", the main Feed table will show dispatches that have been pinned by any user, as well as dispatches currently associated with a VCC incident.

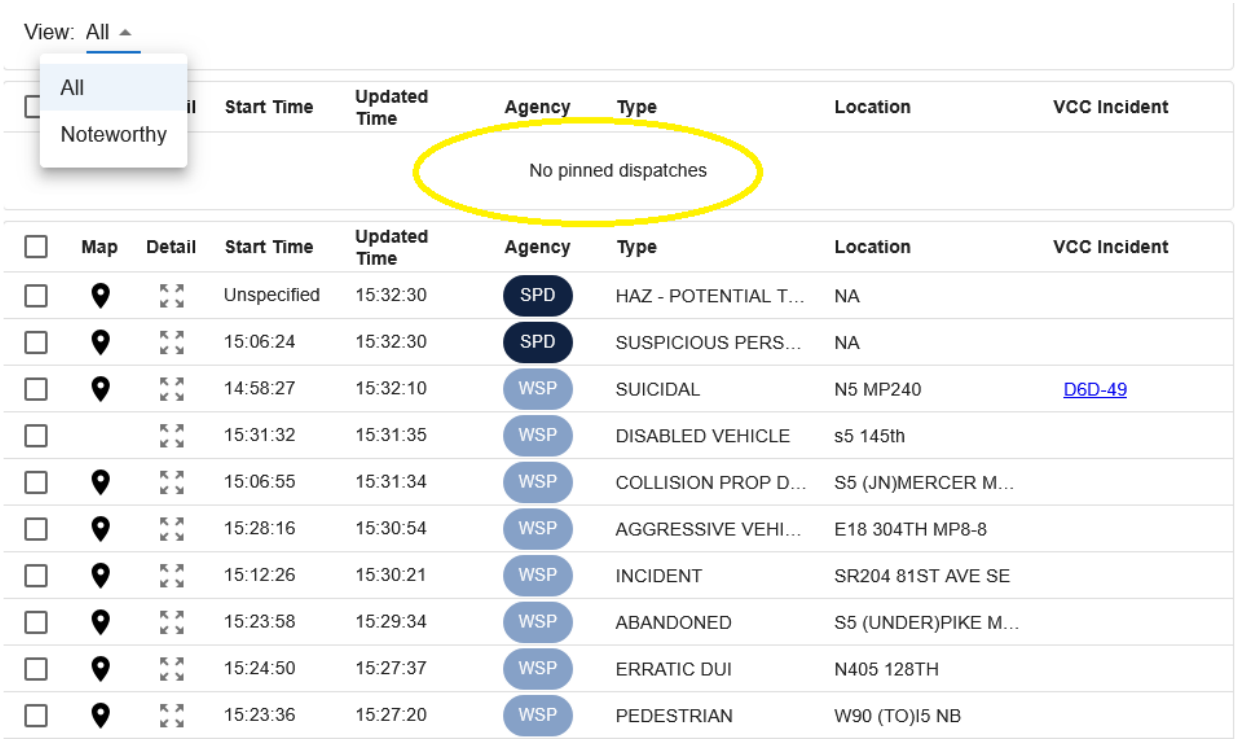

Figure 7.2: A screenshot of the VCC Integrated Dispatch Feed highlighting the "Noteworthy" section of the Feed

The rationale was that if one user thought the dispatch event was potentially of interest, especially if it might "creep" into becoming a VCC incident, other users might also want to be able to monitor it. Members of the design team similarly reflected on whether marking a dispatch record as noteworthy should be considered as an early signal in the VCC that collaboration might be warranted. It could, according to the rubric presented in this dissertation, as a "quantum" of coordination that could lead to collaboration. There were many other similar discussions amongst the design team, which explicitly considered the connection between functional design elements and the very *concept* of collaboration; for example, a design team member once wondered aloud whether placing a perimeter marker on an incident's dynamic map counted as collaboration.

While we had many discussions with operational stakeholders about their perspectives on collaboration, we also had to organize our own approaches internally. We could not simply digest extant stakeholder understandings of collaboration, partly because we didn't have perfect access to all of those understandings, and partly because understanding itself varied from stakeholder to stakeholder. We had to consider implicitly what kinds of impacts would redound from the collaborative system we were building to the broader coordinative space.

7.4.2 Amortizing the Costs of Collaboration

The introduction of any new system creates questions about whether the effort of adopting it is worth the benefit it provides. The VCC design team tried to grapple with the sometimes "costly" nature of collaboration ([68, 42]) and to identify ways to make the benefit worth the cost. As an example of this cost, participants had to think about nuances of the boundaries of incidents in ways they hadn't before. When work procedures are intra-agency, the timeline of an incident follows that agency's standard operating procedures (SOPs). But when an incident management system is shared, different ways of defining and demarcating an incident all contribute to how it is represented in the system. (This could even lead to an agency's internal metrics becoming *worse*, because the VCC's more complete timelines make incidents seem longer.) In this case, more explicit articulation and definition effort is required. During a March 2023 meeting of "agency trainers," or a group of early adopters who were selected to help introduce the VCC to their own agency, attendees had to puzzle over such minutiae. This excerpt was from the meeting's slides prepared by

a member of the UW design team leading user adoption, and regarded a recent real VCC incident, explaining what data were actually input into the incident and checking whether this process was working:

> **Viewing the IM as a collaborative space/agency space**
>
> The IM [incident model: see Section 3.3.1] was closed at 17:36; the WSP dispatch was closed at 18:16; the SPD dispatch was closed at 18:46. So WSDOT closed the IM while the initiating WSP dispatch and the associated SPD dispatch were still open. Thus far, Traffic Centers tend to launch IMs and then close them when they are done. Should an IM be closed by the agency that launched it, or should it be handed off to agencies whose associated dispatches are still open?

Participation in the creation of a system like the VCC requires more people to think past their own involvement in work, and to do so more habitually. This co-creation effort with other people at other organizations extends the cognitive reach of different kinds of work. It makes more kinds of work more cooperative in nature, because people are more aware of other parties' inputs and outputs. This is another influence of the collaborative system on the coordination space over time, since the "shape" of the coordination space includes what aspects of it are meaningfully cooperative and collaborative, and how. That reshaping creates different opportunities, risks, and resources for participating stakeholders at all scales.

Another type of cost that can be incurred is the potential for inefficiency and frustration during new collaborative practices. As many people pointed out, if people opted not to buy into the VCC and use it dependably and effectively, its actual use and purpose as a shared system would not be fulfilled. This sentiment came from both active enthusiastic users, and reluctant or infrequent users. The active users expressed wishes that other agencies would use the VCC more; and the infrequent users said that they would use it more if *others* did. In one case, an interviewee at WSDOT interacted with the VCC aspirationally, saying "I have been trying to use VCC as if it is a vital network of information, as it will someday be." Yet this comes at a cost. Frequent users sometimes bemoaned the extra effort it took to add information to the VCC, and the uncertain benefit of that extra effort. It also created space for new collaborative grievances; now with the VCC, there

were even more people to have expectations of. In a 2025 interview, an SDOT interviewee who had worked at the Transportation Operations Center for several years opined about the imperfectly realized potential of the VCC from his point of view, when asked how the goals of the project have changed over time:

> P5: I think the–how I could phrase it is that, the hopes were high, but I don't think that it's, I know it's a great tool to have, but I don't think we've used it the way, maybe I was hoping to go to the max. Maybe it's underutilized, in my opinion. Only SDOT and WSDOT basically, do work on, on answering actively VCC. [Seattle Police], Metro, Fire totally; maybe they do have accounts; we get their feeds, but they are off hands, at all, hands off. Doing nothing. Mm hmm.
>
> Ridley: OK. And so how would you kind of ideally want them to be participating?
>
> P5: I mean (sighs), they could activate their own incident when there is a major incident. I mean, let's say there's a–I'm just giving an example–there's a shooting incident, but we don't talk about the, the law enforcement part, but if it's going to take and block traffic, they could have more inputs. You know: hey, this, it's closed from here to this road. Rather than us trying to figure out, oh, which roads are they closed, especially if we don't cameras, you know, we go and search for this information.

The interviewee opines that other agencies should activate "their" own incidents, which would both save SDOT and WSDOT some of the documentation labor, and allow authoritative information to flow from the most direct sources. While the VCC is made for shared operation during major incidents, some incidents fall more naturally under the primary jurisdiction or auspices of one agency, with additional inputs needed from others. Yet previous patterns of usage mean that the agencies with an identifiable lead role don't always take the initiative to create and manage the relevant VCC incident. When they don't, users from other agencies can notice and wish for more participation.

SAJOG as a Collaboration Cost Manager

Ultimately, the responsibility for ensuring that the cost/benefit analysis of using the VCC remained positive was only partly ours. We attempted to provide features and information feeds that provided broad benefit, but how fully the stakeholders adopted the VCC was their own decision. The costs varied for each stakeholder, and for some, based on their needs as individual, workgroup, and organizational stakeholders, they were great enough to lead to reduced use. It was, rather, SAJOG whose ongoing advocacy helped build greater positive "inertia" for the VCC over time. SAJOG as a body was involved in convening the people who helped to apply for federal funding, but how central VCC was in SAJOG's activities did vary. SAJOG was at liberty to focus less on VCC and more on other TIM-CM activities, so how much time and effort was spent on VCC matters at meetings had real impact.

After deployment, SAJOG meetings took time to review VCC updates, solicit interest in its use, and illustrate recent incidents and how VCC was used to help manage them. Bringing this to attendees' attention allowed them to discuss ways to make their practices more effective and reinforce the value of the VCC. So the costs of collaboration were actively mitigated and managed by those who bore them. While SAJOG had been stood up before the VCC project began, its position as a VCC advocate emerged over time. This can be seen as the coordinative space growing a new form of stakeholder–a sort of coalition or interest group–that also acts according to its own needs and interests. This is another way a new collaborative system can shape the coordinative space: via the development of new kinds of coordinative units connected to its ongoing promulgation.

This section has illustrated how identifying and working through the costs of collaboration in a new system is itself a part of how the collaborative system imbricates with the coordinative space. The burden of these costs is borne differently by different scales of stakeholders, and is paid through at different speeds. This can make singular objective metrics of cost-benefit analysis hard to align with actual value and burden to users. Looking to the ways coordinative configurations change around a new system–how actors try to create positive "inertia" for new systems–might offer a useful complement to such metrics.

7.4.3 Preplanned Plays

Part of the design team's aim in the project was to help the operational stakeholders articulate a vision of future collaboration, to be supported and partly enacted in VCC system elements. But we were also still learning about what collaboration could mean for this community, and not always with perfect approaches or results. This dissertation is not the post-mortem of an unsuccessful system implementation. The VCC was validated as a successful pilot project and is currently being expanded to nearby jurisdictions. But it *was* a complicated project that required recalculations and reframings in its stewarding from concept to implementation. The dynamic nature of collaboration, its multidimensional forms and levels, and partially hidden internal organizational dynamics, made some components of the VCC particularly challenging to design for. It also meant that even when in-the-world collaborative work happens well–and is improved over time due to SAJOG's efforts–doesn't mean it is always mirrored effectively in VCC system elements. The following example will show how we approached some of these challenges in reference to a particular proposed design element; and how an understanding of scaled stakeholders might have made the process more effective.

From quite early in the design work of the VCC, one component that we expected to build was a feature called "preplanned plays." The idea was to lightly templatize some aspects of managing incidents: by learning how people wanted to coordinate during incidents, we could create some basic plans that could be deployed for incidents of "well-known" types that tended to be managed in a similar way each time (such as, for example, a commercial vehicle crash in a particularly incident-prone area in Seattle). If successfully deployed, this could improve efficiency and reduce coordinative costs for stakeholders, and further build inter-agency communities of practice. These "preplanned plays" could include basic traffic management plans, tasks to reach out to certain secondary partners like towing companies, or information about locations of resource caches.

The basic idea was championed by a WSDOT stakeholder who had experience developing roughly analogous plans for other departments of WSDOT, particularly around defining standard alternate route planning for some of the state's facilities in Tacoma. To begin the work, we led many design sessions, held discussions with small groups of people at individual agencies, ran polls about feature preferences, and wrote elaborate operational scenarios to identify potential processes.

These activities were a major part of our repertoire of co-creation/human-centered design activities, intended to elicit preferences, relevant factual information, and operational constraints from participants.

For example, in a February 2022 design meeting, SDOT and WSDOT participants talked through what kinds of decisions and actions might happen along the timeline of an incident, including when the SDOT control room (TOC) and SDOT Response Team (SRT) would be involved, and how.

> Ako (a WSDOT participant): WSP would likely not respond given location so SDOT would likely call WSDOT from an FYI [a short call from the TOC to TMC to inform them of the situation]
>
> Mitchell (an SDOT participant): TOC would reach out to WSDOT. We would need to determine location of vehicles (e.g., on the bridge, under the bridge, on the shoulder) and also find out if there are any buildings near the bridge being threatened. SRT would be there to secure the area. Charles St. Dispatch would be involved. SRT would be setting a perimeter for crowd control. We need to understand where to route traffic if Yesler Way is blocked. Given that [King County] Metro has VCC, they would also already be aware of the incident. SDOT would coordinate with KCM for rerouting of buses.

In this and in other related meetings, people worked together to understand the availability of resources, the potential orchestration of tasks based on different decision points, and the possible ways that could be represented in the VCC. In so doing, they worked to establish more shared "ground truth" about incident management, and gain greater insight into each others' procedures and decision-making.

Stakeholders labored over potential task orchestrations, and tried to identify the roots of decisions made in other places, such as in this exchange between a Seattle Fire leader and a Seattle Police leader during a session held in May 2022:

> [Seattle Fire Department chief]: usually the trigger that sends out closure info is done through SDOT, but is that a mayoral thing? Who is actually responsible for sending

> that out? Or does it vary? (chuckles)
>
> [Seattle Police Department captain]: it varies depending on who's leading it and the magnitude of each partner's involvement. They're gonna make that determination at levels above ours.

However, to what extent incidents could be templatized or turned into "plays," was a point of disagreement between different operational stakeholders. This was a fairly fundamental and critical issue: it spoke to different underlying beliefs about what was actually possible for structuring coordination and collaboration in the space. In a meeting of SDOT operations personnel, the SDOT Response Team (SRT) manager challenged opinions SDOT control room and management personnel had expressed in the conversation. The control room and management personnel had argued that recommending specific reroutes to drivers (as opposed to giving them more general guidance like "Use Alternate Routes") wasn't desirable. In the SRT manager's view, they are quite feasible, and a part of "integrated corridor management" (a transportation management term referring to "the integrated management of freeway, transit, arterial, and parking systems within a corridor using ITS technologies and innovative practices. It is the management of a corridor as a system rather than the management of the individual transportation networks (e.g., rail lines, bus routes, arterials, freeways) within a corridor"[1]).

> Josephine (SRT manager): Reroutes are integrated corridor management. You can have primary, secondary reroutes and get the message out to take I-405. Need to think outside the box. SRT/IRT takes people off the freeway through arterials and back on the freeway. Need to get people to indicate on the maps and coordinate that response. We can have pre-determined reroutes, have it arranged with signs already: If northbound traffic has one reroute, if southbound has a reroute.

And similarly, discussions with KCM representatives, who manage fixed routes of a known group of vehicles, and therefore tend to have a more structured view of roadway management, described their already quite detailed and mature process of adjusting to incident conditions. The incident

[1] https://www.transit.dot.gov/research-innovation/integrated-corridor-management-icm

scenario being considered was perhaps too severe for full planning, but their standard approach integrates templated reroutes more fully than some other agencies:

> Lisa: do you have specific reroutes if specific things are blocked?
>
> Luke: yes we have a huge [database] of them. But this [scenario] is a special case, as it includes all of downtown. We don't have something in place for something that massive, so we'd do it on the fly. So we'd put an announcement: "all inbound coaches coming west on 15th Ave, park your coach and await instructions." There was an incident at the South Renton park and ride a few days ago; initially we told all buses not to go to South Renton park and ride. We told them to use zones near it and explain to passengers that it is closed. After that, we drilled down and said, "Route 107 do this, Route 150 do that." Once you do that you can drill down to individual routes. That's smaller scale than all of downtown Seattle, but that's the approach.

The work of all of these groups requires improvisation and plenty of tactical and situated decision-making during incidents, but the expectation of structure and bounded, deterministic action is much greater than for some others, when it comes to abiding by operational guidelines. For example, moving specific buses from one finite segment of a bus route to another is more structured and under King County Metro's control than trying to encourage an unknown number of drivers to alter their behavior, and detour from the highway at any number of places and spill onto thousands of city streets.

Challenges of Using Design Techniques to Create Preplanned Plays

Both the operational stakeholder participants and the design team learned a great deal from the activities related to preplanned plays, and many of the participants' insights were incorporated into the VCC's design. However, the actual preplanned plays feature was not built during our work on the VCC project, and lies dormant still. How was such an intriguing, potentially transformative function, which both the design team and the operational stakeholders were so willing to spend so much time and energy on, unable to launch? As always, there are many answers to that question. Time and resource constraints, of course, contributed. But I think some of the issues described

in this chapter also offer some insight. During P3's 2025 interview, they explain how from their perspective, we took the wrong signal from our interactions with operational stakeholders and their appetite for preplanned plays.

> P3: I think it just fell into the classic product definition trap of "seems like a good idea." Most people would nod their head at the concept. But when it came down to, would they actually, you know, vote with their dollars or vote with their time, vote with their feet. It was, It was. Yeah–"I don't really wanna do that," or "I don't see how that'll work." And, and, so I think, I think that's where we, we held on to a feature too long.
>
> Ridley: Hmm.
>
> P3: That the users were telling us, like, we're not, we're not getting it, or we don't want it. That doesn't mean that we should have given up on it earlier. I mean, I, I think maybe we should have, we should have downplayed it earlier. Maybe we should have, you know, gone to the extra effort to really validate what the need was. Maybe there was a different need.
>
> You know, in retrospect, I think we were sort of fooled by the fact that they did have standard operating procedures and scenarios and things, to some extent, and we maybe mistakenly expanded that to that they wanted to create many more. That might be the, the key break point that we never quite got. And, and I mean to this day I would say it's still a good idea. Like, the more these teams can not have to re-figure stuff out in the moment, the better. But they, they still have to figure out lots of stuff in the moment, because every situation is different. So like, we just never really cracked that, if you like.

This extended quotation raises the question about what kinds of signals we were taking as the design team, regarding what the stakeholders wanted for their shared coordination. Standard Operating Procedures (SOPs) abounded, as P3 observed; but SOPs are created to structure an organization's internal self-coordination. Such SOPs direct how people and units behave in reference to an organization's own constraints and policies. An organization's internal constraints and policies

don't always have the ability to handle the complexities of work happening in the coordinative space, even though they often have to be called upon in the midst of shared coordinative work.

Policies are interesting to examine from this perspective because they are sometimes expressed as organization-to-organization coordination and sometimes not. Some procedures are created as if the people undertaking them are acting fully internally and some are not not. Policies guide and constrain the activities of an organization and its members. But because a coordinative space shifts over time in response to many kinds of stimuli, policies and procedures can "leak" into a shared coordination context where they weren't previously active. This can prompt re-adjustment on multiple fronts if the impact is noticeable and salient to actors in the space. An important instance of this "leakage" in the case of the VCC is Seattle's surveillance ordinance, which was passed in 2018 and requires specific scrutiny and handling of technologies considered to be doing "surveillance" under the auspices of Seattle city agencies [2]. While the VCC is specifically not for citizen surveillance, components of its data integrations (such as the Seattle Police Department's Computer-Aided Dispatch feed) could have been considered surveillance impacting. This affected how we handled this data stream, and the terminology we used for it, to manage how we served up this data source to the VCC's users.

Another frequently used design instrument, the operational scenario, also brought some of the challenges of designing with scaled stakeholders to the fore, in this case because of the large numbers of details provoking a kind of "analysis paralysis." Discussions of a potential major incident (in this example, a tanker rollover on I5 with potential hazardous materials aerosolization) would become lively, and people would add numerous additional potential complications, such as planning for pedestrian and bike routes that could be impacted, short-term construction closures that could affect reroutes, and numerous other details which did sometimes have significant consequences for incidents. These interesting possibilities would stimulate discussion, but make constraining it to something actionable difficult at times. A UW design team member expressed the pitfalls of overcomplication in our design elicitations:

> P10: but once we got working on that, then we started moving towards like, well, let's come up with a scenario and see what it is that people think their job is, or what it is

[2] https://www.seattle.gov/tech/data-privacy/surveillance-technology

> that they do during, you know, this type of incident. So a lot of the meetings were spent like, well, how should, what kind of scenario should we design? And at first, you know, we were designing these very complex incidents with like planes, you know, crashing–
>
> Ridley: Alien invasion.
>
> P10: Yeah, exactly. We don't, you know, let's go for something a little less dramatic than that, because a plane into a bridge, you know, requires FTA people to come. And you know it's like, that, that's, let's go for a little bit of a lesser incident.

Working through incidents in such granular detail laid bare how complicated and interconnected incident work was, and also created a level of decision fatigue for determining the right level of detail for preplanned plays. Lee Clarke's [28] *Mission Improbable* put forth the claim that major disaster plans–unflatteringly called "fantasy documents"–often serve more of a rhetorical and social function than a tangible planning function. This is because the events being planned for are not as actually plannable as they are required to be, under the logics of rationality that give rise to the need or desire to create such plans. In a sense, they launder rationality to provide a sense of legitimacy and comfort for constituencies regarding fundamentally terrifying and unmanageable situations.

Preplanned plays were, of course, not full-scale disaster plans, nor were they intended to be. However, I would suggest that *part* of the underlying challenge Clarke grapples with is that of describing different types of scaled stakeholders, which have different ways of approaching the "modelability" or "plannability" of work. In the VCC, for example, the SDOT Response Team (SRT) and King County Metro participants conceived of incidents as being more generally "plannable" than the control room personnel from both departments of transportation did. When these different concepts of work formulated by different kinds of stakeholders are combined in an indiscriminate fashion, complexity explodes in ways that are unexpected and sometimes frustrating.

Had we deliberately modeled our scaled stakeholders and their specific forms of coordination, and different relationships to the coordinative space to account for this, it is possible our understanding of preplanned plays might have been clearer, sooner. It might also have helped us ask more precise questions about specifically what kinds of knowledge and decision-making were available to different coordinative units at different points in time. In a ConOps meeting in May 2022, while our design meetings about the preplanned plays were still winding down, a design team member commented

that "If I had to do it all again, I'd say, people, you're not ready for a collaboration space." What it takes to be "ready" for a collaboration space was something that was, as P3 noted, not necessarily something discoverable either from objective functional need, nor from participant appetite and interest. There were genuine and pervasive *values* of collaborativeness and "cosmopolitan attitudes" [25] across the individual, operational domain, and organizational stakeholders of the VCC project, but it was sometimes difficult to fully tie those values and goals into the orchestration of tasks across multiple levels within the same system.

What we eventually landed on in VCC was a section of the Incident Model called "Mobility Strategies," where people involved in congestion management could indicate actions they were taking or planning to take, such as activating virtual message signs or blocking lanes. In this feature, people could not only indicate their won actions, but also add collaborators on a given action, which would then notify the collaborator. However, they opted not to. Instead, the feature became yet another notification-oriented feature, rather than one where users would directly employ the VCC to collaborate with each other. Users tended to like the capacity to add collaborators, but expressed hesitance to actually use it, as it could feel presumptuous, especially if the collaborator was at a different agency.

7.5 Conclusion

In this chapter, I have laid out the idea of the stakeholder in an inter-organizational collaborative system design project as a coordinative unit, with particular attention to how organizations both act as stakeholders in inter-organizational design projects and condition how their members behave as stakeholders. In a collaboration, which seeks shared outcomes or outputs, different scales of stakeholders participating means that even "shared" outcomes are expressed and experienced in functionally different ways. This model helps to explain some of the wide variety of coordinative behavior in a shared space. Individual participants in codesign activities often contain multitudes as they act as individuals with their own preferences and personal relationships; but also on behalf of their workgroups and organizations.

One expression of scaled stakeholdership occurs when organizations deliberately limit the participation of certain kinds of workers as users in a shared collaborative system. Applying this idea to inter-organizational design projects, requirements elicitations should explicitly inventory

not only what data might be useful and where it comes from; but also what might be required socially to enable a data flow in such a way that the organizational stakeholder that "owns" that data can find acceptable ways to share it. Policy-making, which can occasionally function as organization-to-organization coordination, can both simplify coordination and obstruct it (sometimes both simultaneously). Mapping out such activities *as* coordination can enrich understanding in the research phases of a design project.

It is important to take this network of multi-scalar relationships not as a snapshot in time, but as an evolving dynamic influenced by structural factors (including, in the case of the VCC, the challenging geography of Seattle), political factors, and of course, the personal relationships forged and broken between the people involved. Recall, for example, from the incident scenario in Chapter 5 the PIO who used to work in a different role at a different agency, and can still rely on some of those personal connections to informally find important information. Starting a design project focused on both supporting and reshaping collaboration between many such coordinative units means stepping into a complex, ever-evolving situation. Appropriately contextualizing and historicizing these dynamics is extremely challenging for designers, given the inevitable incompleteness of access to the actors in these dynamics. Yet when done properly, it helps us step more surefootedly into the coordinative space and make decisions that steward collaborative improvements. In the next chapter, I will explore some ways the design team acted in our own way as stakeholders to conceptualize and steward these improvements.

Chapter 8

DESIGNING IN COMPLEX COLLABORATIVE SYSTEM DEVELOPMENT AS DISCURSIVE PARTICIPATION

8.1 Introduction

In the previous chapters, I have focused on systems and collaboration. Now I turn the focus to the people who were trying to bring those two things together in the VCC project: the design team itself. In this final analysis chapter, I will describe some key ways the VCC design team acted as stakeholder(s) in the project. The VCC was a project where complex imbrications of practice and system use, and shared sensemaking about both project values and operational effectiveness, interacted over several years. By examining the design team's experience on the VCC project, I hope to provide some understanding of how projects like these are actually accomplished, and how the social and discursive roles designer-stakeholders take can help them achieve design goals.

Creating a system like the VCC with stakeholders from many organizations requires a lot of communication: making and evaluating claims, resolving disagreements about how interfaces should look and behave, and so on. While this is a fairly obvious point out of context, I would like to take this observation a bit further. How designers' own motivations, opinions, shifting strategies, and frustrations help form the ideas that translate into system elements, and how appealing that translation is to operational stakeholders, can be hidden in favor of explaining how designers extracted and organized what the operational stakeholders wanted. This makes for a cleaner narrative, but puts the operational stakeholders (or subjects) in an asymmetrically vulnerable position beneath the research's analytical gaze, and also does not tell the whole story.

To reveal and complicate this narrative, I will first use a mostly discursive [46] lens; that is, I will pay special attention to the forms of communication that build social interaction and relationships, and allow ideas, beliefs, and values to shape a social situation: in this case, a large design project. I will examine how the VCC's design team (including both UW and Pariveda participants) communicated through documents, activities, and design artifacts to convey ideas and

exert our own agency; and how both the operational stakeholders and the technological materials we were developing "talked back" [112] to us. I will then analyze how we used those techniques and strategies to accomplish our design goals. I will conclude by commenting on what it means to be a design stakeholder in a multiorganizational design project like the VCC.

8.2 Modeling the "Designer" as Active Participant and Stakeholder

My primary research question, *How can designing collaborative systems help interdependent public service stakeholders innovate their shared work?*, asks what participating in design work affords operational stakeholders. This implies a connection to the other participants in this work: the design team, who not only create the desired artifacts but often help to set the terms for how the operational stakeholders participate in deisgn work. The concept of work infrastructure inherently calls into question the sharp distinction between "designer" and "user" (or "client" or "stakeholder") because of its emphasis on the processes of infrastructuring and design-in-use. It reframes end-user system adjustments, workarounds, and refusals as integral to the design of work infrastructure systems.

In this chapter I approach the deconstruction of this distinction from the other direction. That is, I want to examine how we on the design team ourselves acted as stakeholders in the project, different from but equally immersed in the evolving life of the project. I am informed in this pursuit by the ethnographic and sociological perspective I brought to the project, and previous work on design ethnography [10], BOAP [72], cognitive ethnography [162], and related methodologies. As Schultze describes, a "confessional" approach to ethnographic research "highlights the ethnographer's experience of doing fieldwork by giving a self-reflexive and self-revealing account of the research process. It presents the ethnographer's role as a research instrument and exposes the ethnographer rendering his/her actions, failings, motivations, and assumptions open to public scrutiny and critique" [135]. Similarly, I want to unpack how we on the design team acted as subjects and stakeholders in direct and indirect ways, and reveal the very messy and human ways we used to give an account of our experiences through the technologies we created.

8.3 Design through Discourse

It is common for designers in even human-centered projects to express their agency by selecting and organizing structures of interaction with operational stakeholders: the creation and management of, for example, design workshops [126] or UX assessments [86]. These structures, created with design expertise, allow participant agency (and needs, desires, and insights) to emerge in a way consumable by design processes (often as "specifications" or "requirements"). Designers, thus, make critical choices for which activity structures are appropriate and useful, how insights are conveyed and synthesized, and what kinds of assessment questions are asked.

What I will talk about in this chapter is slightly different; that is, I will more closely examine the discursive and rhetorical approaches the VCC design team used over time to explore and advocate design ideas, together with the operational stakeholders, in an often nebulous and evolving design space. We employed some of these techniques during more traditional design activities–which themselves usually have some kind of inherent rhetorical structure, if only implicitly–but also through ongoing conversation, choosing design elements to develop, and preparing policy documents.

While we certainly used strategies to advocate for our preferred approaches, and individuals on the design team had our own goals and desires, I do not wish to frame this chapter in terms of an inherently competitive or coercive relationship. Just like the operational stakeholders, we learned as we went, negotiating with and adapting to the evolving multiorganization even as we sought to provide a design product to it.

8.4 Techniques

First, I will describe some discursive techniques we used to achieve our goals as stakeholders, express our perspectives, and shape conversations in the project. To be clear, this list is not meant to be any kind of thorough typology or framework. It merely represents a few indicative examples from this project; other projects will likely exhibit slightly different techniques, and *how* those techniques are deployed and how effective they are will vary depending on the styles of project management used, and the personalities and relationships of the people involved. It is also not intended to argue that the techniques we did use were particularly rare. Instead, it is meant to demonstrate a different way of reporting on and describing common but under-reported activities.

8.4.1 Terminology

The first technique I will discuss was the coining (or introduction to this context) of project terminology. This may seem like a facile observation: in any design project where systems, user roles, and features must have names, some level of coining and neologism will take place. In the VCC, the design team's creation of potential project vocabulary also played particular discursive roles that help to illustrate how we expressed our own stakeholdership to accomplish (and adjust) our goals.

Characterizing the VCC System

One important usage of neologism was to communicate about the ideas and values the project was meant to express. The name of the Virtual Coordination Center itself is perhaps the prime example. Before the VCC was developed, many stakeholders spoke in meetings in terms of a "virtual command center," analogous to the physical command centers that are commonly employed during major incidents. The suggestion and socialization of the VCC as a virtual "coordination" center by the project's director instead allowed us to begin suffusing the system with the collaborative values we wanted to emphasize with the system's development. It should be emphasized that this value and goal of collaborativeness was something the participants largely supported and actively sought our help in supporting. So this selection of terminology wasn't the design team trying to force a "rebrand" of the project, simply a rhetorical reinforcement of the notion that coordination, not command, is the core focus.

Another example later in the project was the creation of the "mobility strategies" section of the incident model, where users who help to manage the roadways (putting up overhead highway signs, closing lanes, etc.), could collaborate with each other. This language of "strategies" was both a callback to the previously attempted "preplanned plays" I discussed in the previous chapter, and a way to convey shared "strategizing." This was important because the City and State have separate overhead highway signs that have occasionally provided conflicting advice to road travelers. The need to coordinate messaging for mobility activities was something we wanted to encapsulate here as something the VCC would help address.

Redrawing Boundaries

Another function of creating terminology was to redraw the boundaries of work. For example, early in the design project, we began listing the different potential "operational communities" who would use the VCC for different work functions. One such community were public information officers (PIOs). At their respective agencies, PIOs are responsible for communicating to the public, media, politicians, and internal leadership about important events and activities their agency is taking part in. When representing this operational community, rather than calling them "PIOs," the UW project leader coined the term "Population Movement," often shortened to PopMo. This somewhat more abstract terminology served a few different purposes for the project.

First, it shifted the focus from one particular job type–a job which, in many agencies, has many tasks outside of traffic incident management. For example, law enforcement PIOs often hold press briefings if there are major crimes or officer-involved shootings, even if there is no traffic impact. Renaming this operational community to "population movement" allowed a reorientation to the outcomes of their work relevant to incident management: communicating to the public to get the population appropriately moving through the transportation system during and after disruptions.

Second, it permitted the inclusion of other work relevant to "population movement" that wasn't usually considered part of PIO work. For example, customer service personnel at the agencies often participated in these same functions of communicating to the public about ongoing issues, but usually through the medium of service alerts or fielding questions from customers.

And finally, this renaming created a space for people to think differently about the kinds of work that can take place through the use of the VCC. It sought to reinforce that there was something distinct and new about this collaboration; that it was not just the bringing together of an existing configuration of work roles, but a reconsideration of those roles and how they function in major incident work. This was one way in which we shaped the coordinative space beyond the VCC interface itself, by fostering ideas about what the coordinative space was for, and what made it special.

Creating New Operational Vocabulary

At times, our attempts to create new terminology would implicate an actual behavior change on the part of operational stakeholders, and this was where it was more challenging to carry out. Early in the project, we proposed creating "common vocabulary" for the VCC's users, since the agencies naturally share much, but not all, operational jargon, and misunderstandings and mistranslations occasionally happen. As a complement to other VCC functions, establishing a shared lexicon of operational terms was connected with moving toward an aspirational "common operating picture" for the whole operational community. This was a bit different and operationally higher stakes from coming up with different labels for parts of the system. Instead, it was about coining a new operational *lingua franca* that the different agencies could agree upon and use both while entering data in the VCC and while coordinating outside it.

This idea arose early in the project. A September 2019 ConOps draft, originally created by the SDOT executive who was co-leading the subproject at the time, stated plainly the connection between improved collaboration and a shared "SAJOG-wide" terminology:

> Improved collaboration a) Implement standard SAJOG-wide terminology and guidelines/procedures for responding to and reporting all key timelines of a traffic incident through roadway clearance–not as a forcible replacement of local terminology, but a useful shared vocabulary that is well understood and unambiguous

Another early ConOps draft from November 2019, this one initiated by a UW team member representing a UW technology transfer office that occasionally participated in the VCC project, focused on the technical value of standardized representations of locations, and a "usable common vocabulary":

> Incident location and the need to standardize representation of location (e.g. mile marker, call location, lat long, intersection, physical address
>
> Incident type (e.g., collision, disabled vehicle, etc.).
>
> The system should provide for a usable common vocabulary without requiring users to learn entirely different terminology.

This did, however, include the caveat that such a lexicon should be of manageable size and novelty; not requiring an excessive amount of new terminology.

This strand of work was an extension of attempts to build common tools and instrumentation. It was also, explicitly, a recognition of the importance of having common terminology for rapid and fluid shared operation during urgent incidents. But this was not something to be done without extra cost, as implied in many of the excerpts. Creating common terminology meant making people *learn* common terminology, and use it fluently during incidents. This possibility struck some participants as problematic. For example, in a UFR1 (Use, Feedback, Refine) discussion where we floated the idea of a VCC "glossary," a Sound Transit participant expressed concern at the idea. A WSDOT participant (who was also a liaison to the design team) gently pushed back at this concern, but ultimately concurred that the idea of using all new vocabulary during incidents was probably untenable:

> Diane: I, I think number one, we should not rely upon people to figure out what words mean. So I was a dispatcher of the patrol and there are very specific ways they say and do things, for everything. And most other law enforcement agencies are like, they don't even know what we're saying. So, I would say that, and they think it's ridiculous and I get [it]. [It's] just how that agency works, but sometimes people say things and they think that's what it means, but it doesn't. I think, adding tool tips is probably your only solution here, in the middle of an incident, nobody has time to look over a glossary of terms. ... Katie: yeah I think it's probably a both to be honest, too, I think that there's I think you know, the more we can make the terminology common between agencies, the better. But I agree, people are not going to change our ways just because they're using the VCC, especially when you have agencies that are using the VCC for things in Seattle and may not be for incidents elsewhere. And you know, thinking about WashDOT, Patrol, you know, Sound Transit, Metro, etc. And you know how do we, how do we help familiarize that language? I don't think there's harm in having a glossary or some sort of a, here's what something means, reference. But yeah, the chances of people looking at it, especially during this are not super high, but I will say you know, the more you hear those terms, the more you opt in.

Because of the urgency and rapid development of incidents, clear and efficient communication is paramount. This was an operational value that all the stakeholders held. Our proposed solution of creating shared terminology both potentially *improved* and *worsened* this particular collaborative challenge, since it would require an unpredictably significant learning curve, and would require a great deal of negotiation to identify common terms. The prospective difficulty of resolving this tension led us to pivot away from this particular strand of work–or at least defer it to a more mature user community with plenty of shared system use under its belt.

In creating novel terminology, we hoped to connect the dots between the familiarity of current operations and a potential, still-evolving future state. We also used terminology creation to reinforce and recapitulate the operational and collaborative values the operational stakeholders expressed an interest in. However, novel terminology could also create problems at times. The project of creating "VCC terminology" that users would be expected to learn and use during incidents was a bridge too far during the design project. Stakeholders (both individual and scaled) were still figuring out how much they wanted to participate in VCC work at the time these discussions were taking place, and an extensive shared vocabulary would have required them to be "all in" while we were all still constructing the contours and commitments of the project together.

However, proposing new terminology in a project is also a kind of discursive experiment. Seeing it this way, rather than simply as functionality that was rejected by operational stakeholders due to imperfect design work, allowed us to gather data from their responses. In our more or less unsuccessful attempt, we learned a bit more about how the stakeholders actually thought about collaboration and its limits. This then influenced how we created additional functionality, tending to locate neologism in the names of interface elements and user roles rather than in direct coordinative processes.

8.4.2 Storytelling

Another very important discursive technique the design team used was crafting illustrative stories and narratives. Stakeholders from different agencies and work groups could gather and discuss these stories, evaluating their accuracy for describing the pre-VCC current state of incident collaboration, and their plausibility for making certain changes or improvements for future collaboration.

The development of operational scenarios was a particularly important and rhetorically flexible type of narrative. Operational scenarios, used often in concepts of operation and similar documents, are narratives of relevant events (in the VCC's case, major traffic incidents) whose inputs, processes, and outputs help to illustrate the need for a new system and how it might operate. The design team created several operational scenarios with significant input from operational stakeholders, making their creation a key site of dialogue and discovery with participants. (I go into great detail about certain uses and impacts of operational scenarios in a recent paper about the ConOps [77]; what I will cover here is largely separate from those findings.) We fact-checked details with them–technical terms, jurisdictions for certain decisions, etc.–and often built the scenarios from tales of real incidents in the past that struck participants as being especially challenging to manage, or illustrative of collaborative problems they had previously experienced, and thus contained details they found most interesting or informative.

The scenarios were seen as being important for accomplishing different project goals. In a 2019 ConOps meeting, prior to the start of VCC software development, we discussed holding design workshops to work through possible scenarios and explain "the context of the story so far."

> Next step, have the workshops to explain the context of the story so far. Have that context of the storyline and why they need to fill their aspirational "to be" as a community. The difficult part is the integration of the three (PopMo, CM and IM)

This was portrayed strategically as making it clearer to participants why they needed to work toward the project's future vision.

The persuasive power of stories was employed for several purposes. Because there are so many players in a collaborative system like this, without one single stable point of view, focusing on certain points of view in parts of our narratives helped us emphasize different collaborative possibilities. Such choices were far from neutral. In the final version of the ConOps in February 2022, an operational scenario was used to depict how a major, challenging incident might be managed once the VCC was available, and how a large number of distinct VCC stakeholders might interact with it:

> King County Metro Transit Control Center operators saw the congestion management activities of other agencies in the VCC and calculated the impact on their bus routes.

> Bus drivers reported on locations of heavy route backups. Transit Control Center operators sent dispatches to reroute bus drivers and added additional buses to help ease traveling delays. All these dispatches appeared in the VCC, updating the evolving incident model. The reroute information was recorded as well. The King County Metro PIO distributed information to the traveling public on modifications to schedules and other transit advice. Sound Transit operators tracking the incident in the VCC recognized a likely impact on travel to and from their recently opened Roosevelt Link station. They retweeted other agency tweets and provided travel advisories to public information media their other channels for informing the public

In this excerpt, we made the narrative choice to emphasize transit and public information officers in the scenario. This scenario assisted us "designing the collaboration" by casting different types of participants as "characters" in the story of a major incident. Until this point, transit partners and public information personnel had been consistently involved, were not centered as the "core" user base. Some of this was due to their own availability to participate, and some due to the trajectory of our design process–the Population Movement-specific functionality was among the last to be completed. The value they produce and receive was foregrounded in this scenario. This was created to show how the VCC could benefit a wide range of operational stakeholders, and how greater participation would yield value in the collaboration as a whole.

Storytelling about future VCC functionality and the unique ways it could enable better decision-making also took place. A good example of this comes from a document prepared in December 2021, which contained draft operational scenarios meant to be used both for the Concept of Operations and for design workshops. Like the extended incident narrative in chapter 5, all of its specific details are fictionalized, but are based on historical incidents and common experiences. One section of the scenario describes a hypothetical future incident that would happen when the VCC was made available. In the story, an SDOT Response Team (SRT) driver who is also a VCC user indicates information about backups in a VCC incident model page, and this information cues WSDOT TMC personnel to contact SRT's dispatch, which enables closer and more effective coordination between SRT, IRT, and the TMC, leading to a ramp closure and communications to the public:

> In the Notes section of the VCC, SRT Unit #10 noted the increasing backup of traffic as

> cars exited I-5. A Washington State Department of Transportation (WSDOT) Traffic Management Center (TMC) operator was also observing the response via the VCC incident model and upon seeing the photos of the backup provided by SRT #10 reached out to Charles Street Dispatch via a phone call to discuss the building congestion and the danger of the downed SCL power pole. They agreed that the I-5 Ravenna exit ramp should be closed in an effort to prevent further congestion and a phone call was made to WSP to dispatch a WSDOT Incident Response Team (IRT) to close the ramp. The TMC operator recorded in the Notes field that IRT was on their way to close the ramp. Approximately 30 minutes after the collision was first reported, the TMC operator notes that the I-5 Ravenna exit is closed in the Incident Model Notes. SDOT TOC and PIO are notified of this update via the Incident Model. The SDOT PIO updates this information via their original tweet, which is then retweeted by WSDOT.

This description of a collaborative process enabled by future VCC functionality was aspirational even after the VCC came into common usage; it is essentially a showcase of a best case scenario (at least within our own imaginative capacity). This form of "future-casting" [137] that we occasionally employed helped illustrate to the operational stakeholders why they should bother buying in to the VCC, and incorporate it into their processes. In this way, it was deliberately a persuasive tactic. However, it was also used as a design probe [56] for those who read and responded to it, particularly during workshops where it was used. By inviting people to react to these scenarios, we were able to learn about their own thinking, and what might become possible for them under different conditions of work and collaboration.

8.5 Goals and Strategies

The VCC design team used discursive techniques like storytelling and creating terminology for a number of strategic purposes, to help the team accomplish our goals as stakeholders over time, managing our mutually effortful co-creation relationship with the operational stakeholders.

8.5.1 Socializing and Negotiating the Design Process

The design approach we brought to the VCC project, organized on participatory, human-centered principles, necessitated communication to the operational stakeholders about the design process itself. This is of course common in any kind of professional partnership, but was particularly relevant in the VCC project because our design project approach was relatively unfamiliar to many participants and could, at times, be uncomfortable or confusing (or seem like too much work). Because of our commitment to co-creation, it was also functionally necessary, if we were to actually achieve design outcomes.

One way we socialized our design process was communicating to operational stakeholders about how it allowed us to adapt and learn. During a design workshop in 2022, members of the design team explained to operational stakeholders how the design team's understanding of the project had changed over time, expanding from understanding and supporting what goes on at "incident sites" (essentially, the focus being on on-scene incident work) to broader issues of coordination and collaboration:

> We went into this project claiming it was about this incident site; but eventually we realized this has a lot to do with collaboration and coordination between people on an incident site and others–it's a bigger issue than just managing a site.

This signaled to the participants our *own* learning process. It showed that we were perceptive and responsive, and able to reformulate our understandings of the design space as we learned and interacted with it. We would then, the implication went, be able to produce better and more useful designs.

We also used texts of agreements and policies to express how we wanted the operational stakeholders to participate in design and co-creation. In an early (fall 2019) ConOps draft, such agreements were listed alongside descriptions of their other roles in the project:

> At the highest level, agencies and individuals working within the VCC environment and accessing capabilities within that environment agree that:
>
> 1. Individuals with access to the VCC will be trusted partners, and participating

agencies will collaborate to define and implement a security layer that assures this trusted status.

2. Individuals working within the VCC will operate not only as members of a partner agency, but also as part of inter-agency operational teams based on role and mission (e.g. the traffic incident management team–TIM, the congestion management team–CM, and the population movement team–PopMo)
3. Participating agencies will collaborate to make ongoing VCC design and development decisions; decision makers will include, as appropriate, individuals from these agencies who are working within the VCC environment. These decisions will determine the design of user experience (UX), delivered capabilities and information sharing, build versus buy of capabilities, and the design of decision support tools.

This excerpt focused on the operational stakeholders' *shared responsibility* to participate in the design process, a key aspect (both logistically and philosophically) of the co-creation approach we were trying to socialize with them. However, this was written in 2019, so what that responsibility actually meant was not clear to everyone involved. Over the next four years, operational stakeholders were asked to expend the effort necessary to participate in design and governance activities, and offer us access to their workers for workplace observations and interviews. In an enterprise this ambitious and potentially risky, it was no surprise that individuals and scaled stakeholders expressed skepticism from time to time, and probably felt even more than they expressed. We had to actively manage this working relationship, continually following up with participants, and carefully crafting meetings and presentations to re-establish the value of the process and the products. The ongoing, only partly visible dynamics of decay and new growth at each agency meant that their value proposition was also not static–something we had to adapt to over time as well.

Over the course of the project, the design team also prepared a range of graphics explaining our vision for the co-creation process, and how we expected the project to proceed. Like the propositions described above, they combined rhetorical and descriptive functions. Different metaphors were used: for example, the idea of the VCC was sometimes represented as a "house" where the different operational subcommunities resided (represented in Figure 8.1). This created both a conceptual tool to understand the different components of the system, but also supported the idea of the

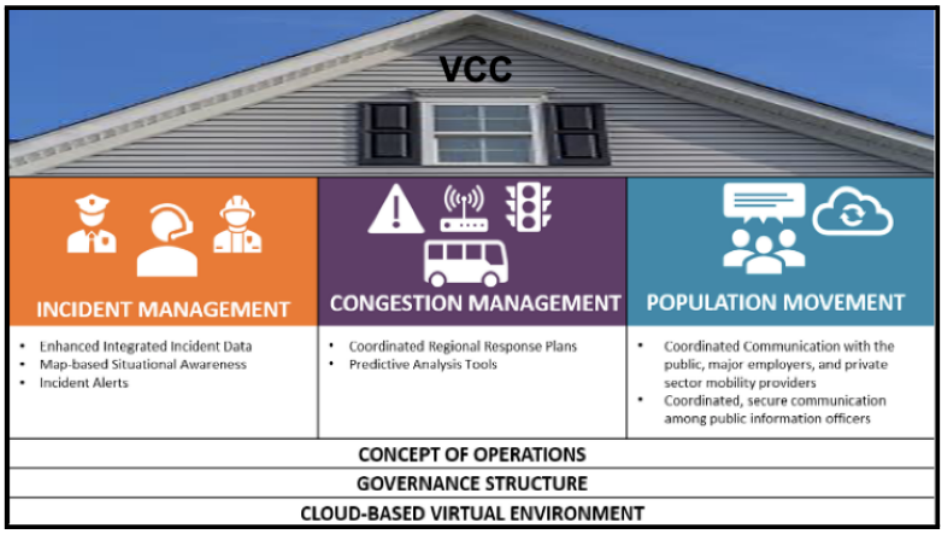

Figure 8.1: The VCC "house" diagram

different operational subcommunities as a "family" that "lived" together in their shared use of the VCC. Other such graphics included depictions of the major areas of work of the project as "waves" of effort; and project governance structures showing connections between different "workstreams," to name a few.

Communicating to the operational stakeholders about how we were designing, and why, was an important way we expressed our own stakeholdership, as it involved explaining through the project what parts we had to play in the development, deployment, and evaluation of the VCC as a system. The example above where we explained our evolving approach away from an exclusive concern with incident sites was one such moment. Others included discussions in update meetings where the principal investigator explained the reasoning for our co-creation approach, not only instrumentally, but philosophically. This invited the participants in to learn alongside us. This in turn helped us maintain a pipeline of their participation during the hard and contentious work of co-creation. For most participants, VCC work had to be done in addition to their usual full-time jobs, so the case for their additional work on the project had to be made continually.

8.5.2 Connecting the VCC's Functions to Forms of Collaboration

Another common type of proposition the design team made, usually in policy documents like the ConOps or in presentations at meetings, regarded how we expected the future VCC to be used: expressions of our collaborative philosophies in terms of our functional design proposals. Relatedly, we provided characterizations of the collaborative values and agreements of the project–connected to, and sometimes mediated by, expected VCC functionality.

An early ConOps draft (from 2019, months before active VCC development started) proposed that while many VCC incidents will directly involve a subset of the stakeholders, every stakeholder is responsible to contribute "as needed":

> Not every agency will necessarily participate directly in every incident, but every member of this community will be made aware of these messages and will be expected to contribute as needed. [This might be a little provocative but Jeffrey and Katie indicated that people should be willing to pitch in even if their agency doesn't have purview over the specific incident, so left it in for the purposes of discussion]

This is an example of deliberately provocative text, to get readers to consider the stakes of being a part of the VCC's operational community. This invited consideration on the part of the operational stakeholders regarding what participating in the VCC as a system and as an operational community might mean for them.

Another early ConOps draft explained some of the rationale for getting full buy-in from the participating agencies:

> To be most effective, the VCC and the ConOps require buy-in from all agencies. In turn, both of these instruments must provide value to all agencies... In time, agencies that are not currently part of SAJOG will be attracted to participate because of the significant value that the VCC and ConOps provide, creating a virtuous cycle of ever-improving communication, coordination, and ultimately service delivery and quality of life for all travelers in the greater Seattle area

The excerpt was an early attempt to express the importance of VCC buy-in, and even claiming that the VCC would be a draw for additional organizations to participate. To a meaningful degree,

this claim was borne out by experience. As of my 2025 interviews, several new jurisdictions are being onboarded as users, and some less directly involved agencies like Sound Transit have people who are showing renewed interest in using the VCC, particularly after hearing accounts of its usage that they missed out on by being less involved.

We predicted there would be other kinds of collaborative benefits in committing to VCC use. For example, in the following ConOps draft prepared in September and October 2019 primarily by me and a UW professor who worked on the ConOps subproject from summer 2019 to winter 2020, the text proposes that control center operators and congestion management analysts will gradually learn from each others' ways of working:

> With the understanding that TOC/TMC operators and CM analysts use similar data sources to address similar issues, the organizational structures and technological tools these groups use should promote productive information sharing between them. Operators will learn the basics of how CM analysts use information sources and create models, with the opportunity to ask questions and give inputs. Likewise, CM analysts will learn about how operators triangulate their in-the-moment monitoring of real-world phenomena to make decisions and propagate relevant information.

Similarly, another early (2019) ConOps draft described a future where the VCC would have a role in promoting regular cross-training between agencies and operational subcommunities, and the enrichment of collective expertise, encouraging "exploration and learning" among frontline operators. Both of these examples emphasize the shared learning the VCC should support; all of the partners inputting data in real time, and discussing that data in the creation of SOPs and in debriefs after incidents, are meant to strengthen a sense of being in a shared community and gradually building shared expertise. The examples also exemplify how policy document text created during design projects can, implicitly or explicitly, reason about how systems and behavior will be connected. Operational stakeholders must accept, reject, or re-negotiate that reasoning.

A ConOps draft from January 2020 stated that the VCC "environment" would offer users "multiple paths to build and share their traffic incident situational awareness from a single, current, accurate, common frame of reference. This is critical to building trust, teamwork and ultimately more efficient collaboration and decisions/actions from common understandings that can save lives,

time and costs in responding to a traffic incident." The text is making a claim about the importance of the VCC's functions to achieving SAJOG's ultimate goals of trust building and the quality of collaboration around incident management. It also supports our design philosophy by portraying the flexibility of "multiple paths" to share information as being operationally valuable.

Similarly, a much later version of the ConOps written in 2022 stated that "through after-action reviews and other methods, agencies will work openly to assess VCC collaborative activities and use those findings to iteratively improvise [sic]." (Candidly, this was a statement I personally advocated for, as I had aspirations that the ConOps would be a truly "living" document that was just as open to reconsideration and reworking as the rest of the project.) The text placed emphasis on the part of the operational stakeholders not only to co-create the VCC, but to assess and refine it over time: establishing a pattern of expectations that would go beyond designated pre-deployment design activities. Yet because the ConOps was being created for a nascent multiorganization, it could not rely on specific organizational rules or guidelines to set behavioral expectations. Rather, it had to rely on persuasiveness and how the text aligned with readers' aspirations for collaboration, and what they themselves considered achievable.

8.6 Conceptual Challenges and Design Outputs

The VCC design team used various techniques and strategies, such as the ones described above, to accomplish the work of design. Our strategies to exercise our project stakeholdership supported our ability to work through some of the difficult conceptual challenges of the project, and by doing so, to output the interfaces the operational stakeholders would be able to use in their work. In this section, I will walk through some of these challenges, and the work we did to address them.

8.6.1 Establishing Correspondences

One of the major conceptual challenges in a project like the VCC, which seeks to support effective shared effort in a multi-organizational environment, is to identify what relevant artifacts, data points, or processes meaningfully and coherently "go" together. Such difficulties are endemic to this kind of work, and why such complex participatory methods as Soft Systems Methodology [23], and analytical methods such as Situational Analysis [27], needed to be developed. Within the multiorganization's diffuse and ever-embedding and imbricating arrangements of practices, job

roles, systems, and data structures, it is often not obvious what work and data are truly "of a kind," in a way that should be combined into a single cohesive interface view. Different agencies do not even demarcate major incidents (the very conceptual backbone of the VCC system) in the same ways and with the same timelines. For example, some consider an incident "closed" when traffic is flowing freely, while others consider it "closed" when all personnel and equipment related to managing the incident have been removed.

I call these associations between potentially analogous practices, job roles, systems, and data structures, which may be represented in a collaborative system, *correspondences*. For designers to make a claim that certain correspondences are meaningful and suitable to include in a new collaborative system also implicitly makes claims about what kinds of work, data, and processes are or should be associated in a coordinative space. Both to *discover* and to *make a case for the existence of* such correspondences in a digestible and accessible way, we had to use all of the techniques described above. In social and organizational terms, we created text to re-emphasize shared membership in operational teams. For example, in a ConOps meeting in October 2019, we discussed how "At some point the responders begin to realize they are apart [sic] of the team that can affect CM in another location," implicitly claiming that participating more thoroughly in the VCC reveals these correspondences and shared membership in an operational community. This pointed to a correspondence of the kinds of work people did related to traffic management, in this case one that could be activated in the minds of participants by working together more and better.

Identifying and creating pipelines for the right kinds of correspondences was a major part of the technical work the design team did as well. When a set of correspondences has been established, work must begin to appropriately represent such meaningful, operationally relevant information in a system. The VCC's Integrated Dispatch Feed is a particularly important example of the process of establishing and refining correspondences, identifying how to represent what data items "go" together, and grappling with the complexities of aggregating a large universe of sometimes conditionally relevant data.

Representing and Constructing the Integrated Dispatch Feed

The Integrated Dispatch Feed (IDF) was one of the first major elements of the VCC. Several of the participating agencies individually maintain computer-aided dispatch (CAD) systems. These systems are used to record key information about a wide range of urgent situations, and to allow an agency to dispatch responders to handle the issue on scene. For Seattle Police, Seattle Fire, Washington State Patrol, and other public service answering points (PSAPs), CAD records usually start with 911 calls from members of the public. The King County Metro CSR (Coordinator Service Record) system, which is also included in the IDF, is different. CSR records originate when bus drivers call in to the KCM Transportation Control Center with any kinds of issues they experience while driving; anything from low level problems like a fare box malfunctioning, to major crimes or incidents they witness. Each record in all of these systems is given some kind of label or type (such as "Collision Unknown"), which can be changed by dispatchers if circumstances change or new information about the event is obtained.

As described in the incident scenario, this CAD data is often the first source of information about an emerging major traffic incident, so it was understood from early in the VCC project that allowing a wider range of VCC stakeholders to see more of it could help the community respond more efficiently and effectively. This design need was what eventually led to the creation of the Integrated Dispatch Feed. However, this is easier said than done; CAD systems are usually long-lived systems operated and infrequently modernized via complex vendor contracts, and CAD records are often rife with sensitive data that would not be appropriate to share widely. This posed many political and technical challenges for the VCC project.

While each of the agencies that contributed dispatch data–Seattle Police Department, Seattle Fire Department, Washington State Patrol, and King County Metro Transit–had deep knowledge about its own structures, and there were of course significant commonalities (record creation time, current location, problem description, etc.), there was still effort required to bring all these records into a single rubric.

For example, while the location field (a critical data point for any incident) was still being defined for the VCC's incident pages, we learned that among our source systems, location was defined in no fewer than eight different ways by the agencies, not all of whose meanings translated readily

between them, as enumerated in a requirements gathering spreadsheet prepared by the developers on the design team: *"Roadway (e.g., I5), Direction (N, S, E, W), Nearest Street Address (e.g., NE 145th Street), Milepost (e.g., 174.58)... 761 Arterial Standard: Street Address (e.g., 27th AVE NE), At/Between, Street Address, Description (e.g., right shoulder, right lane, etc.), Direction (e.g., NB, SB, All, etc.)"*. This created hard choices for the VCC, because all of these different ways of conveying location had to be brought into a coherent, glanceable view.

In an internal design document related to the creation of the Integrated Dispatch Feed, the technical design team identified a need to create a data model that "normalizes" the dispatch events to a common format via API (Application Programming Interface) specifications:

> Dispatch Event Model Definition
>
> a. Create a VCC Dispatch Event Data Model that will be the "normalized"/common view of a dispatch event across the different agency dispatch Models
>
> i. This should be specified in Open API 3 specification
>
> b. Define/Refine the "VCC Event" Model that will wrap the Dispatch Event Model ...
>
> 3. Data Set to Dispatch Event Mapping a. Define a clear mapping design of how each dispatch feed will map to the common "VCC Dispatch Model"

This strand of work required mapping existing feeds to an abstract (shared) technical structure. We were creating this technical structure, and by doing so, and presenting the results to the operational stakeholders, we were making a claim that data fields, and the human work those fields represented, could be placed side by side to provide a coherent understanding of the state of the transportation system. This was a technical task, but it was also clearly a discursive act as well.

To identify both what was usually "traffic related"in the source systems, and try to uncover whether certain event types tended to be connected to more serious incidents, we presented a list of event types from the four source systems (King County Metro, Seattle Police Department, Seattle Fire Department, Washington State Patrol) to a selection of operational stakeholders in January 2021. We asked participants to rate how worthy each event type was of their attention (or indicate they weren't sure); how often each type might indicate a VCC-level incident; and how often different

types of events could potentially pertain to the same incident, such as if the Fire and State Patrol CADs both had events regarding the same multi-vehicle collision on I5. We used the findings of this exercise to begin building out the Dispatch Feed, and later to build out triggers that would automatically create VCC incidents based on the dispatch record type. For example, because the Fire department CAD's record type "Car Fire Freeway" was identified as being frequently worthy of attention as a possible major incident, the VCC's automated triggers created a VCC incident when such a record came into the feed.

The team came to realize that the feeds themselves were not static, and that individual records did not always have the same relationship to categorizing major incidents. In User Story 683, the design team worked to log "true negatives" and analyze "false negatives" regarding which dispatch event types should be filtered out of the Feed's data pipelines at each source. This would then potentially feed into a configuration file that VCC technical managers could use dependably to manage the feed even if the sources changed.

> Each agency dispatch event has 1 or more fields that indicate the type of event (incident). There are 300+ event types across the agencies, however a subset of these events are considered "always irrelevant". Additionally, each dispatch may add, change, delete event types making it difficult to keep an up to date enumerated list of all possible types. This story describes a capability to pre-filter dispatch events using a list of excluded event types so that only (possibly) relevant events pass through the system. Logging of discarded events should be kept to support analysis (e.g. is there useful info in a field previously thought irrelevant). Finally, the intent of this story is for a configuration file approach to be used a) via Sys Admin action based on D&D [Design & Development team] input, b) without requiring redeploying VCC components, c) updates take effect within a reasonable time (10 minutes).

Relatedly, in User Story 479, titled "Congestion Manager Integrated Dispatch Feed View," the design team reasoned through how to represent the feeds coming from the data sources, with "non-traffic-related" records already filtered out before they arrive in the interface. Questions arise in the comments of the user story about how to do this, and whether there is conditional logic at play. For example, a major incident might involve records outside the pre-defined geographic region or

having a type not normally associated with traffic problems:

> If we know that we only care about data within a geographic region, and that qualify as "traffic-related" we would ideally filter these out in the data-pipeline and not do this while users are viewing events This will improve performance and simplify logic. This also gives us more time to define what events from each system qualify as "traffic-related." Suggestion: For this story, we assume these records are already filtered out by logic in the data pipeline (i.e. a different story will account for this filtering/processing of events in the pipeline). Once we do further analysis, we can determine if this logic is more conditional (i.e. sometimes we want events outside of our geographic region, or non- traffic related) we can add logic at that point to account for these requirements

What these user stories are conveying, in part, is that by learning about the agencies' data practices, we came to understand better how challenging it was to have a full definitive representation in the VCC of everything that was truly relevant. Internally to the technical side of the design team, this strengthened the connection between "core" system data and analytics, in terms of the team's own desire for learning and information about the contextual and contingent meanings of records, to enable deeper understanding of what was "truly" traffic related. This meant that we had a different stake and interest in incorrectly associated information than the operational stakeholders did.

The design team synthesized significant input from the operational stakeholders, and numerous material and technical constraints, to "construct" the idea of a general supra "dispatch event," of which each current individual agency's feed could be seen as a subset. That is, we weren't simply reproducing slots for existing items to be placed into, we were also iteratively developing new concepts that could be used in new ways. Once the Feed was initially made available, in fact, the Seattle Police Department's IT security managers saw SPD's own data in the context of the Feed and the associated map where dispatch events were plotted; and asked us to redact previously available location information. The creation of this representation, then, changed operational stakeholder behavior in the context of the project.

Pariveda's VCC project lead (P3), commenting on the process of developing the Dispatch Feed, explained how they felt the technical and conceptual design of the Feed was in some ways "simple,"

but that there were many possible ways of representing the data that weren't fully explored.

> [O]ne, one of the things that was important from the design standpoint is that we, we—It was so simple, conceptually, right? They each had these CADs, and like, we're just gonna stick them together so everybody can see them....But it was there, that like, you know, we'll just have the 4 feeds, like, going next to each other, like, we're not going to integrate them yet. We're just gonna pull them together. And so I mean, I, I think, for that one, like it was conceptually so simple that, you know, we could easily come up with different, different levels of integration. And we could talk to them. And it was, you know, the challenge was just getting the data. And like I mentioned, like KC Metro data was totally different, like. So the fields didn't map, and things like that. I think, I think one thing that we really could have done better was explore different ways of visualizing that data that might have been more intuitive, more useful, more insightful. But again I go back to that, like, like, the, the stakeholders were only able to accept so much new stuff, new change at a time.

In this excerpt, the interviewee was trying to put a name to the tension between the apparent simplicity of representation and the challenges of establishing the right kinds of correspondences between what different things should be represented. Our technical choices for the Dispatch Feed enacted a certain version of these correspondences and representations, which bumped up against the ability of users to make sense of it. In the same interview, P3 described some of the challenges of developing the VCC incident model particularly in reference to the KC Metro data stream, which was portrayed as an "orange" to the "apples" of the other data sources. This reveals just how challenging it can be to know where the boundaries of correspondences really lie.

Another design stakeholder, P4, reflected during in their 2025 interview that perhaps *all* the participating agencies might have had CAD-like systems that could have been consumed in the VCC; there simply wasn't sufficient time to learn about and map out all the potentially meaningful correspondences. Even with thoughtful and effortful human-centered design methods, designers can get "anchored" at an early approach to proposing correspondences, and how this affects the trajectory of the forms of representations that result.

Identifying and establishing organizational and data correspondences served several purposes for

the design team, and discursively supported our stakeholdership. By proving out correspondences, we were able to establish our important role in the project of the multiorganization (of which the VCC design project was a very significant but not the only component). It helped us to make a case for pursuing certain design objectives, such as the placement of the Integrated Dispatch Feed into a single table in the interface. It also helped us to play a role in the shaping the stakeholder community, by being able to claim that people in a wide variety of roles are part of the same "team." This also helped with traditional stakeholder management [79] tasks like making requests for additional data. Instrumentally, identifying meaningful and useful correspondences also supported our own investigations and explorations into the extant universe of data, organizations, and work.

While building and validating the Dispatch Feed, we iterated through configurations of the source systems, technical discovery, and adjusting to the material constraints of the technology and the evolving viewpoints of the operational stakeholders. In grappling with with so many latent difficulties of representation, something new–the abstract notion of the "VCC dispatch event" as something distinct from the computer-aided dispatch records the VCC consumed into its Integrated Dispatch Feed–was created. Through the process of establishing correspondences between the dispatch feed sources, iterating ways to represent a useful and usable subset of their universe of records, and conveying the value of the new Feed to the operational stakeholders, we expressed our own interest and stakes in the project.

The VCC Incident Model: a Construction and a Reconsideration

The VCC incident model (IM) serves as a helpful comparison to the conceptual work of establishing correspondences and thereby creating new constructions that occurred with the IDF. The IM was a more obvious and deliberate case of construction rather than representation. It was meant to represent work done on a major incident, but new forms were also created for it, and the fact that users from different agencies could edit these forms at the same time meant it was a novel informational product.

As described in greater detail in Section 3.3.1, an IM can be created by a VCC user, or automatically when certain kinds of records appear in the Feed, when a potential major traffic-impacting

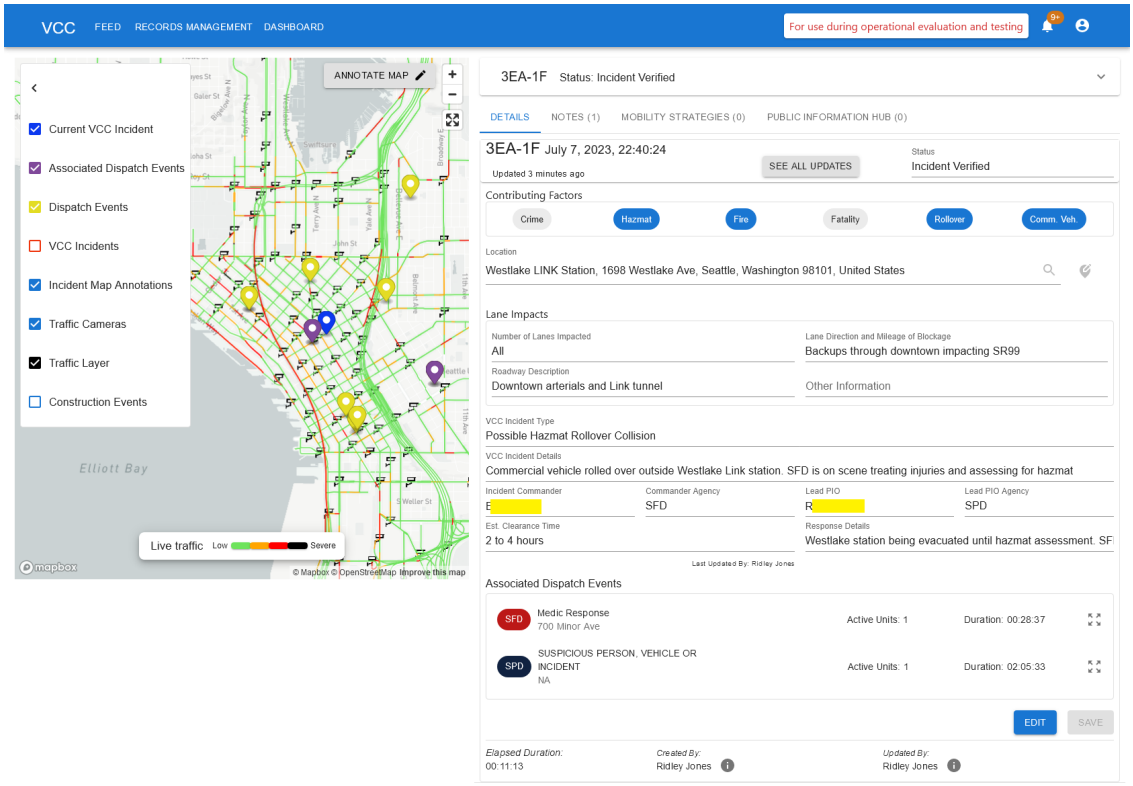

Figure 8.2: Example of a VCC incident model page, with some information redacted

incident has begun. Automated triggers and users can create IMs from dispatch events, or manually if there is no associated dispatch event. The IM page has a variety of information available to view and edit, including a regional map that can be annotated with road closures or blockages. Users can update many information fields pertinent to understanding, coordinating around, and resolving the incident. All updates to fields are captured in a running log, which can be viewed by clicking "SEE ALL UPDATES." Once the incident's work is completed, its status is changed to Closed, and it no longer appears on the VCC's dashboard, but can be temporarily viewed on a Reporting page. See Figure 8.2 for a sample Incident Model.

First, the name of the "incident model" itself is another example of strategic terminology development. The idea of a "model" is a deep one with a storied history [107], but what it suggests in context is an attempt to represent meaningful parts of something with an underlying, not perfectly representable ontology: namely, the immensely complex major traffic incident. Since the agencies

also delineate major traffic incidents in different ways, everyone in the VCC's operational community worked on major traffic incidents, but no one had exactly the same understanding of what a major traffic incident was. This created a different kind of design challenge for us, with different expectations and responsibilities attached to its accomplishment. The VCC incident model ultimately presented a part of the collaborative vision for SAJOG and the VCC multiorganization. For the design of the incident model, we engaged in frequent dialogue with operational stakeholders to identify broadly useful fields (such as Location, Incident Commander, or Predicted Duration, and some third party information such as traffic data) and processes (like changing the status of the incident or marking incident-related road closures on a map). Its process of construction invited intentional discussion about what a major incident *was* for the operational stakeholders; and what it could become given desired changes to information presentation and collaborative workflows. Throughout the design process and later during operational deployment, users' reactions to the nascent model were incorporated in design activities, but how users chose to create and use Incident Models in the real world–often in ways we did not expect–helped to continue this conversation even post deployment.

In that the creation of the Incident Model was an intentional construction of a new form, there was a danger in reifying collaboration too exclusively in the system, rather than in the community who use it. This was a topic of conversation among both the operational and design stakeholders. In VCC practice, some stakeholders embraced conducting actual coordinative actions in the VCC (such as adding notes directly informing specific partners about actions being taken). Others explicitly stated that most collaboration happened outside the VCC (often in phone calls), but that the VCC was an excellent place to *record* collaboration. Members of the design team were not of one mind either. When asked how they would have approached the project differently, P3 moved their thinking closer to this simpler recording-facilitating approach, saying that

> Well, from what we did, we brought the data in, um, and put it in one place. Going forward differently, I think I would just have a much simpler view of that, and then focus more on the interactions outside of the platform to gauge what we should do, uh, inside of the platform.

So the implementation of the Incident Model's structure, the ways users adapted it in practice,

and even how Standard Operating Procedures around VCC usage developed, were all ways to renegotiate what collaboration meant for the VCC's broader coordinative space, and to re-examine the ontology of a major incident.

8.6.2 Synthesizing

The Integrated Dispatch Feed was a subproject aimed primarily at representation, but whose conceptual and technical complexities led to a new construction of traffic-related dispatch data; one whose conceptual work was arguably not even complete by the end of the project. The Incident Model was more deliberately connected to the construction of new data fields and interfaces, and so the design team's responsibility to make claims and decisions was clearer for the IM. However, because it was available to be used and adapted by users in many different ways, its creation was readapted by users, as described in previous chapters.

Because the project was explicitly about creating a flexible system to support evolving collaboration between several organizations with a wide range of potentially relevant resources, there was ultimately no clear line between representation and construction. This insight is supported by Chongthammakun and Jackson's previous work on virtual organizations [26], which computationally bring together functional aspects or workflows from multiple organizations. They find that "forms of intra- and inter-organizational coordination that go beyond traditional boundaries, and may go to the core of organizational function, requiring government units to adapt their internal business processes, incentive structures, and roles vis-à-vis outside collaborators" [26]. That is, creating these correspondences and putting them into "conversation" with each other by sharing interfaces spurs reconsideration of the meaning and use of the sources being used.

The design team consistently argued that co-creating and using the VCC would help the operational community move toward an evolution and innovation of practice. It wasn't, however, obvious what the connection would be between that evolution and the system's actual elements. Pipek and Wulf, when describing work infrastructure [117], predicted this challenge:

> Design methodologies require designers to define a design scope (for example, a particular device or software artifact). Doing this requires defining what is internal (things to modify/design) and what is external (issues to consider) to a design process. Parts of

> the work infrastructure will be (and need to be) excluded from design, but the complexity of the work infrastructure makes this a difficult and error-prone process that may require corrections later. These decisions often remain implicit and are usually not part of a design methodology.

This nebulousness sometimes proved a challenge for the technical members of the design team; a developer on the project noted to me in a 2025 interview, for example, that they *have memories of [P3] just repeating, what problem are we trying to solve? And just saying that over and over again. So, there were days, I guess, when we were at an impasse for what we were trying to design* (P4). P4 also, however, told me that the unusual experience of "green field" research in the VCC equipped them with analytical skills they've since brought to other projects, particularly regarding handling ambiguity and being able to build an application from the "ground up" rather than based on a well-established framework. What was challenging for the operational stakeholders about this ambiguity made it challenging for us too; and we all learned from the process.

8.7 Conclusion

In design elements and workshops, and in policy documents and government structures, the VCC design team attempted to shape the VCC's collaboration space, and provide appropriate rhetorical resources to nudge it toward what we thought best. Through these activities, we strengthened institutional relationships with the agency stakeholders, and as individual humans we learned and grew through our experiences.

In this chapter, I have described how we used different discursive and rhetorical techniques to act as stakeholders in the VCC project and accomplish our own goals. I have deliberately turned an analytical eye on the design team to understand how we negotiated and iterated ideas in dialogue with the operational stakeholders, leading to the particular constructions and representations that formed the VCC. Discourse and argumentation are significant tools for collective meaning-making, organization-building, and social relationship development [150, 6, 47]. Designers' use of these tools in a design project–sometimes even subconsciously–makes it more possible for them to do the kinds of complex design work these imbricating coordinative spaces require.

While I believe there is value in simply describing the empirical data I've presented, I also hope

that this account will provide more clarity for understanding how outcomes are conditioned by designers' interests and values, in a dynamic give-and-take with operational stakeholders. While we did not have the same kinds of stakes in the completed system of the VCC that the operational stakeholders did, we had many kinds of stakes in how the project ran, which grew and changed over the several years of the project. Being honest and reflective about those stakes can help other design teams better unpack their own motivations, and be more explicit and creative about how their approach or philosophy can support the work of design. As human-centered designers and CSCW researchers, we often seek to investigate the needs, concerns, dreams, and anxieties of operational stakeholders, while making it appear that our own are irrelevant or are located solely in the design methods we explicitly adopt. Instead, we are neither tyrants nor servants, but co-creators of evolving and imbricating structures.

Chapter 9

CONCLUSIONS, SYNTHESIS, AND IMPLICATIONS

In this dissertation, I have told the story of one particularly complex design project: a collaborative system built with and for traffic management personnel in the Seattle, Washington region. Using a candid and ethnographically informed engagement over several years, I have sought to offer designers and scholars some new concepts for describing and analyzing inter-organizational coordination, and systems that support that coordination. While this dissertation has covered fairly wide ground, its core contributions are around increasing our theoretical understanding of inter-organizational work infrastructure, and how inter-organizational design projects can both shape these systems and spaces, and offer perspectives on better understanding them. I hope that this work will help analysts (both academics and practitioners) see these projects in new ways. Through this analysis, they can more accurately and creatively map out who is acting in the coordinative space; understand the dynamics of work infrastructures within and across participating organizations; and meaningfully participate as stakeholders in the shared work of the project. This can then equip them with tools to ask better design questions and adapt methods that will get to the heart of what these collaborations are *for*, and what they mean for their active participants and the wider public they serve.

I have attempted to answer my research question, *How can designing collaborative systems help interdependent public service stakeholders innovate their shared work?*, by examining three different components in turn: the interdependent stakeholders, their dynamics and histories of work infrastructures, and discursive interactions with designers. If I could answer that question in the briefest summary fashion (which I have otherwise used this entire dissertation to do), the answer would go as follows. Multi-scalar, interdependent public service stakeholders shape their own interdependence in a coordinative space, by discursively engaging with designers to establish correspondences and constructions that can then reshape that coordinative space. In doing so, they navigate their partial information access, the decay and new growth of systems, and distal systems

shared among other organizations, to improve connections between acting, perceiving, recording data, and coordinating, in service of shared domains of work. They bring this knowledge, and these approaches to "infrastructuring" systems they use, to the co-creation of new forms with designers of collaborative systems. This agentic, strategic, dynamic process continues after the collaborative system is deployed, and changes the shape and size of the coordinative space, and the embeddings of their own organization's work infrastructures, over time.

As systems experience decay and new growth, they provide new opportunities for infrastructuring and reconfiguring working relationships. The development of a new collaborative system like the VCC creates opportunities for CSCW and infrastructure studies scholars to study decay and new growth within specific participating organizations; a kind of observational study of the response of current embeddings to a new stimulus. Designers have a role in selectively visibilizing different forms and scales of coordination in the interfaces we develop, which creates speculative spaces for people to identify and develop correspondences between "like" datasets, workflows, or other artifacts used in shared work. The intensive exploration of correspondences and the creation of new constructions shape the coordinative space, through both shared learning, and changes to coordinative actions [92] in mutual use of the new system. This can enable exciting innovation in shared practice, though because different stakeholders view a given collaborative process or output in different ways, it may not always look like "innovation" to all stakeholders at the same time. Part of the co-creation work designers can do in these settings is to help participants learn what is innovative to each other, and how their differences can spur them to think differently.

Each organization adopting a new collaborative system integrates and embeds that system differently. Patterns and expectations from prior experience with distal system embedding can influence that integration. Optionality and ambiguity, and even the challenges of partial access, can be strategic resources when adopting a new system. A design project isn't just a design project, it's a pathway to infrastructuring at a more meta level. That is because it encapsulates and provides correspondences for stakeholders to model and push forward their inter-organizational infrastructuring aims.

These concepts can be useful theoretical springboards for researchers who want to undertake ethnographic study of inter-organizational technology design and use. There are, for example, many possible causal connections that could be identified, and more detailed typologies of (e.g.) distal

systems or coordinative units. This is an excellent opportunity to bring in multi-site methods such as BOAP, and create biographies of artifacts that have multiple identities across locations, and of practices that have different meanings at different scales.

9.1 Summary of Concepts Introduced

Before proceeding to the specific implications of this dissertation for researchers, designers, and operational stakeholders in multiorganizational coordinative spaces, I will briefly summarize the concepts I have introduced.

9.1.1 Distal Systems

When organizations are in an interdependent coordinative space with each other, they often help each other with their work by establishing distal systems: systems developed or operated primarily by one organization, but shared with others, usually in a somewhat limited form. These distal systems don't behave in the same ways as their system of origin, since they are brought into settings where they are not embedded in the same way, and often without the same type of supporting infrastructure and expertise.

9.1.2 Embedding via Partial System and Information Access

One of the primary contentions about systems I have made in this dissertation is that partial access to systems or information is an important and pervasive aspect of how work infrastructure embedding happens. Partial access can be *de facto* or *de jure*, or a combination of the two. Partial access affects how people can actually make use of their systems, how they understand the ways data pass through these systems and the processes and relationships around it, and what "hooks" they can perceive for potential infrastructuring activities

9.1.3 Dynamics of Work Infrastructure Decay and New Growth

An organization's full portfolio of systems and work infrastructures can, of course, experience rapid major changes. However, over a work technology system's long lifespan, most of the ways it fits, or

loses fit, with the organization it serves change in more gradual ways. I have used the metaphor of *decay and new growth* to capture this heterogeneous, gradual, and interconnected dynamic.

Decay and new growth happen continuously and simultaneously, and how they are managed and perceived depends on a variety of factors, including the kind of work the work infrastructure supports. Moreover, the same process can sometimes be perceived as decay or new growth, depending on the perspective being taken. This means that there are usually countless unobserved "niches" for evolution or adjustment of technology usage. When we observe a system that has been decaying and growing within its ecology for a long time, we might see strange and beautiful things. An artistic rendering of such a system can be seen in in Figure 9.1. This piece, "Cosmic Listening Device," comes from Portland, Oregon's speculative anthropology museum, the Zymoglyphic Museum. This unique museum displays "art, artifacts, and natural history of the [fictional and supernatural] Zymoglyphic region." Thr Zymoglyphic region's peoples and biomes freely blend the natural, artificial, scientific, and spiritual."Cosmic Listening Device" is an artifact from the Rust Age, "so named because many of the ceremonial artifacts were made of decaying metal, which was thought to have a sublime quality of character and texture of age. In some of the artifacts, the rust continues to decay and eat away at the core of the object." [1] The device both feeds on, and feeds, the natural area around it, as it continues on its long-term technological task.

9.1.4 Negative Coordination

As coordination becomes more complex, and where participants have goals and requirements that are occasionally at odds with each other, different varieties of negative coordination can arise. These are instances of coordination that are still part of the portfolio of work people do, but that have an emotionally negative or structurally antagonistic character. Negative coordination occurs when entities in a coordinative space need to navigate locally conflicting priorities, even if they have compatible long-term goals. Coordination mechanisms [134], standard operating procedures, and policies are among the tools used to manage negative coordination and any resulting fault or accountability. These forms of coordination are often challenging to identify in design projects, but are still part of the coordinative space in a meaningful way.

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[1] http://zymoglyphic.org/rustage.html

Figure 9.1: "Cosmic Listening Device." Credit Jim Stewart of the Zymoglyphic Museum. Used with permission.

9.1.5 Scaled Stakeholders

The notion of scaled stakeholders in collaborative projects can help designers and researchers to connect complex coordinative dynamics to design project activities. A scaled stakeholder has an identifiable structure, commitments, and constraints by virtue of being composed of not only individuals but supporting structures–such as, but not limited to, charters or written policies–that scaffold its persistent identity. A scaled stakeholder contains smaller scales within it or as meaningful parts of it, with the smallest scale being an individual person. Structural distinction and meaningfully different "stakes" differentiate these stakeholders, rather than numerical size alone as the only criterion.

Designers can use this concept to make sense of the inputs and outcomes of building particular interfaces and workflows, and the varied ways stakeholdership can be expressed. This idea broadens the analytical lens researchers and designers can bring to a setting, allowing them to see a wider variety of activities and signals as being forms of coordination relevant to the collaborative system or coordinative space; and orienting ideas of use need and desirable functionality around supporting these different forms of coordination.

9.1.6 Modeling Designers as Stakeholders

My attempt to expand and problematize the notion of a project stakeholder was paired with an examination of designers themselves (ourselves) as stakeholders. I described various design activities as discursive techniques, with the design project functioning as an extended dialogue about what collaboration could or should mean for the VCC's operational community. These discursive techniques supported the thorny conceptual work of aligning extant data and workflows, and new constructions, with these collaborative aspirations.

9.1.7 Establishing Correspondences and Constructing New Collaborative Forms

A large part of the intellectual work in the VCC project, and I believe in similar projects meant to support collaboration in an inter-organizational coordinative space, is to identify correspondences between "like" items. These correspondences can then be used to make a case for thinking about collaborative relationships in new ways. For example, claiming that there is a substantive corre-

spondence between data sources owned by two different organizations helps to make the case that the management of those sources and the use of the data could be more closely aligned. New forms and interfaces can be constructed around these correspondences, to allow new types of information-sharing or work to complement and extend the correspondences.

Work in cyberinfrastructure on the idea of data integration as coordination [108] employs a similar concept to analyze the ways scientists integrate their partly overlapping scientific data. The authors identify activities that "establish the foundation for collaboration in making the very existence of particular data types known, as well as facilitating discourse around the possibilities of reuse of those data for one's own research questions, and the viability of labor arrangements which would enact those integration efforts" [108]. What I am discussing here is a slightly specialized case: correspondences are established specifically between data that might be used in a coordinative space for the purpose of supporting and improving shared work within a collaborative system. Further, the process by which correspondences are identified and brought up for consideration means making claims about the nature and possibilities of coordination in a new system. In other words, there is a specific interaction between the correspondences and role of the design project in defining and developing the coordinative space.

9.2 Refining and Extending the Notion of "Work Infrastructure"

One of the key ideas used in this dissertation has been Pipek and Wulf's concept of "work infrastructure," the "entirety of devices, tools, technologies, standards, conventions, and protocols on which the individual worker or the collective rely to carry out the tasks and achieve the goals assigned to them" [117]. First, while work infrastructure is characterized in terms of its complexity, pervasiveness, and flexibility, conceptual work around this idea doesn't fully take into account the longer-term infrastructural processes of an organization. Partial access, and decay and new growth, conspire to embed versions of the work infrastructure that don't strictly align with the objective structures and functions of the systems. The de facto work infrastructures that get embedded over time–those that are actually within the reach and understanding of real users–can be seen as "holographic" versions of the actual work infrastructures. More problematically yet, because decay and new growth, and partial access, are ongoing processes, these holographic work infrastructures are moving targets. Attempts to innovate, or address "points of infrastructure," must take place

against both the explicit and objective work infrastructures and against the salient holographic work infrastructures, in order to accomplish the actual goals of improvement.

Examining work infrastructure by comparing its structures and processes between interdependent but structurally distinct organizations, as has been a focus of this dissertation, yields some additional aspects to consider. If we think about people's work in reference to their inter-organizational coordinative spaces (and even more importantly, when there is a shared collaborative system or distal system), people's concepts of their assigned tasks and the nature of their work occur in reference to these external entities. The greater levels of coordination and interdependence, the greater the possibility for work infrastructure within one organization to influence the work infrastructure of a partner organization. Pipek and Wulf do address external influences when discussing "standards" that can affect system usage (such as the global internet); however, they provide relatively little detail about this aspect. This is partly because of their analytical focus–if the researcher is primarily analyzing one organization, then what is "external" can be understood in a fairly broad way. What is important is the boundary between "within" and "without," and external forces can come from many directions. However, when one is studying an explicitly *inter*-organizational setting, there is no one single locus, only numerous angles and intensities of information and influence between systems. As designers/designers-in-use grapple with this idea, useful knowledge of these dynamics can help them to frame their discursive engagement with the varied stakeholders. They have a role, which they must undertake with care, to visibilize specific parts of these influences, and make them susceptible to shaping and changing.

9.2.1 When the "Point of Infrastructure" is Inhibited or Hidden

Finally, I would like to more closely examine the idea of the "point of infrastructure." The point of infrastructure is, according to Pipek and Wulf, the moment when the infrastructure becomes "visible," either because of a breakdown or in more positive terms, the awareness of a new usage. In the conceptual framing of work infrastructures and infrastructuring, they are a key crisis point that can lead to design-in-use. However, as explained in this dissertation, there are a number of processes that can inhibit or hide these potentially fruitful points of infrastructure. The combined use of other systems undergoing decay and new growth can compensate for potential breakdowns.

The heterogeneity of decay within a single system can make its more problematic aspects less visible. The decontextualization of support and development that can occur when organizations use distal systems can make the paths to constructive infrastructuring vaguer. This suggests that designers and designer-users may have to look more broadly and deeply for these potential points of infrastructure, and be willing to unpack apparently smooth and adequate functioning to do so.

Meanwhile, design work can be the cause, not only the result, of points of infrastructure, especially in inter-organizational projects. The sometimes painful or even embarrassing work of elucidating the realities of "current state," both to designers and to external partners, can reveal obscured inefficiencies even well into a design process.

9.3 Implications and Further Directions

I will now outline some more specific implications of this work for researchers and practitioners in inter-organizational collaborations, in hopes that this dissertation will have both practical and intellectual value in its application to other settings.

9.3.1 Implications for Researchers

This work offers several implications for researchers working in CSCW, infrastructure studies, and generally in the design of complex inter-organizational systems.

Conceptual and Theoretical Implications

The model of distal systems put forward in this dissertation raises potentially fruitful questions for future investigation in other inter-organizational coordinative spaces. For example: Is there a disparity in positive outcomes at one target organization vs. another, and what local work infrastructure dynamics contribute to these differences? Does the source organization extend greater privilege or trust to some target organizations than others; and if so, why? Do IT personnel at the source organization find it harder to maintain the system at some target organizations than others? What makes it more or less possible for attempts at infrastructuring at target organizations to "bubble up" to the source organization? Centering these systems in analysis should be a goal of ethnographic design research.

How and why distal systems are shared with target organizations is a kind of mirror of collaborative relationships and the coordinative units in the coordinative space, since it can help to establish and strengthen shared data jurisdictions. Tracing distal systems' historical trajectories in detail–something I was unable to do in this dissertation–remains an under-explored research opportunity. They create a chance for an empirically driven differential study of functionality and of embedding. For example, when the source context is removed at a target organization, what makes it harder or easier to integrate a system as work infrastructure? Future work should examine how this atypical form of "layering" influences a system's ability to help manage the complexity of work. The decay of distal systems at the source, which can then cause them to be unusable at target organizations, is another important opportunity for analysis. There are also numerous avenues for more directly studying what kinds of situational awareness, common field of work, or distributed cognition are impeded are supported by specific instantiations of distal systems.

There are, as previous research has identified, costs to collaboration: financial, logistical, social/emotional, even political. Embracing new collaborative systems also has those costs, and they are expressed differently for different scales of stakeholders. They are also "paid out" in different ways as the system is incorporated into active coordinative work, and new coordinative forms can emerge to manage them. The study of, for example, coordination mechanisms [134] or boundary-negotiating artifacts [90] can be enriched by attending to how the costs of collaboration are paid out in reference to them (and by whom), and how this changes as the item comes into broader use.

Design-focused researchers have the opportunity to use the development of a new system as a kind of probe or experiment to learn more about the connections between system use and inter-organizational dynamics. Operational stakeholders navigating their partial access, making sense of it, and in some cases trying to circumvent it, contributes to the particular ways work infrastructures get embedded and "sunk into" organizational practice. It follows that if a new system is brought on that expands information access, especially if it is noticeably more "open" than other systems, new relationships and ways of working should emerge. Some of these possibilities may prove a source of surprise or perceived lack of control on the part of organizational management. This is, of course, an empirical question that future work should take up.

This dissertation provides researchers with a new lens to study the trajectories of complex work infrastructure systems, using the dynamics of decay and new growth. Degradations of some parts

of systems can be masked, depending on how the health of the overall system is conveyed between decision-makers, and which functions of the system are invisibly supported by workarounds (such as, in the VCC context, the unusably slow mapping feature in the Fire department's onboard system, which was supported by individuals using smartphone mapping features). This can give those working on upgrades or system replacements incomplete understandings of the stability of systems and the potential urgency of updating them. Organizations often have technical employees who help to manage system lifecycles, but I suggest that this heterogeneity can make a full understanding of these lifecycles incomplete.

Future work should more closely examine how, when these different scaled stakeholders are at play in the same project, different scales try to exert influence and agency in different ways, and how direct and indirect responses or challenges to those attempts arise. For example, workgroups who seek to exert influence by shaping types of workflows or terminology by virtue of professional expertise may be challenged by organizational stakeholders bringing apparent obstacles in the form of policy. Similarly, "coalitions" between scales may result in unexpected expressions of coordination. How, then, do designers model these influences and try to resolve them in the interfaces they create? To what extent do their own values and interests filter the ways they create and enact these models? And after the design project is over and the system has begun its life in the hands of its operational stakeholders, how are those designers' interests reinterpreted and recruited for future infrastructuring? This line of questions offers researchers a way of observing the interplay of influence, stakeholdership, and system elements throughout a project, and a sociomaterial lens on the complex imbrications of the social and technical in a large coordinative space.

The framing of the development of correspondences enables more effective study of the social interplay between designers and operational stakeholders, which can then help the researchers better understand the process that leads to the design product. How correspondences are identified, and how "deep" they are portrayed to be, offers designers the opportunity to demonstrate expertise and value for operational stakeholders. It creates opportunities for both operational and design stakeholders to make arguments about what subsets of the coordinative space should be aligned and how. This can be a place where designers' own stakeholdership can express itself, in that these conceptual discussions can give rise to usable interfaces. By presenting artifacts that they consider acceptable and worthy of presenting to operational stakeholders, designers are advancing

notions of what forms of interaction in an interface provide value. This can be analyzed as a kind of participatory epistemology of the coordinative space, where the interface's structures point to what knowledge structures are meant to be productive and salient for coordinated work.

Method and Reflexivity

Law [88] has previously described the difficulty of trying to simplify social scientific engagements with the world, and the "mess" that often results. He argues that method is not "a more or less successful set of procedures for reporting on a given reality. Rather it is performative. It helps to produce realities." Confronting this "messiness" can be generative.

In this work, I have reflected on the experience of a project where I held many roles and performed many activities over several years, both within and without formal research structures. The challenges I experienced juggling the different parts of the sociotechnical milieu I was actively participating in, and what kinds of knowledge could potentially be drawn from it, made it difficult to assemble, organize, and navigate my dissertation research data. How could I be sure I was being rigorous enough if my attention so often had to be divided, and my access to research instruments was so contingent? However, what I did not appreciate during the VCC project was that retroactively assembling, organizing, and navigating the data for this dissertation helped me to produce its very insights, in ways I would not have been able to had the road been straighter and clearer. For example, my analysis of stakeholders as coordinative units arose partly from working through the complexities of keeping our research and design activities acceptable for the stakeholders, and coming to understand their responses to the potential risks involved in innovating their work. Similarly, our tactical and nimble attempts to continue aligning stakeholders' stated desires for collaboration–continually negotiating agency over the narrative of the project–revealed to me the importance as discursive and rhetorical techniques we used to express ourselves as stakeholders, particularly as they were adapted throughout the project. It also helped me to understand that these tactical adjustments and negotiations with the world we engage with as scholars happens in any research engagement; but that the analytical value of those unexpected adjustments remains to us to create.

If we as design ethnographers, ethnographers of design, design researchers, or any such con-

figuration of roles, think of ourselves as project stakeholders, this creates a particular kind of responsibility for us. We must consciously "manage" ourselves as stakeholders, and communicate forthrightly with our fellow project stakeholders about what our own goals, desires, and motivations are. In the VCC, as in similar projects, we didn't have sufficient continuous access to operational stakeholders to always get their opinions for making specific design choices or gathering thorough ethnographic data, so we had to make many judgments ourselves. Even as a purely practical matter, designers' own preferences do shape the designs, even in very human-centered or participatory projects. Adequately reporting on these preferences makes for a less "neat" story, but taking on the challenge of doing this also offers new opportunities to more fully describe the phenomena being researched.

It may have occurred to the reader that negative coordination and partial access are similar in that they are both analytics of the gaps, or the shadows; they are important phenomena that happen outside the explicit and predetermined structures of coordination or system use, in the tradition of other methods like BOAP [73] or theoretical frameworks like Suchman's plans and situated action [149]. This is true; indeed, I would claim that seeing what is happening in the gaps and the shadows, and how the rest of the surrounding sociotechnical structure responds and adapts to that, is important for an honest sociomaterial study of any complex system.

9.3.2 Implications for Design and Operational Stakeholders

In the context of inter-organizational collaborative work infrastructure development processes, this dissertation offers some potentially valuable tools for designers, who certainly have their work cut out for them. In particular, the ideas presented in this work provide some new ways of analyzing stakeholders and gathering requirements

Designers should investigate histories of distal systems when undertaking the design of a new collaborative system. This will not only help them avoid potential pitfalls in integrating new collaborative systems, but also enrich their understanding of the coordinative space and to identify patterns of system adoption and sharing that they can learn from.

Users can employ partly overlapping systems to triangulate information, creating more resilience for the task. So even if there is a "competitive" dynamic at play between different embedded systems

in the same organization, even "competitor" systems can blend and overlap, especially for critical data verification during fast-moving operations. In this case, disparate forms of data gathering and presentation can actually be an asset for situational awareness. What can be presented as a rationalization effort to remove redundant systems can then, without fully understanding how these systems are combined, make analysis worse.

Time is both a challenge and an opportunity in complex, inter-organizational design projects. The complexities of decay and new growth, and partial access, can make asking the right questions difficult in the early/exploratory design stages, when it is not yet possible to fully understand the historical context of the coordinative space. The language stakeholders use to characterize the health of systems undergoing decay and new growth, and the perceptions they have around their effectiveness, can therefore lead designers to form incomplete impressions about the functional gaps new systems might fill. Further, the gradual decoupling of system functions to work processes that can occur during decay can be hard to observe and diagnose in real time. This decoupling can manifest as hesitation or shame in users that they are "failing" to use a system effectively, or fatalism about the possibility of improvement. Such signals may "suddenly" appear only under a novel stimulus like a design project, but have longer histories or manifestations. Being present for a longer-term project offers opportunities for handling these issues, but the designer has to be willing to notice such changes that may appear to be outside the scope of specific design activities.

Goals and values are critically important when designing for collaboration, but it can be easy for designers to get stuck at early stages of investigation, because phenomena like negative coordination can be hard to observe and awkward to discuss. An inter-organizational coordinative space having broadly shared goals doesn't mean all interactions within that space will happen in non-conflicting ways. A thorough assessment of the coordinative space in service of developing a collaborative system likely includes accounting for this; they do not go away just because they are not acknowledged.

The kinds of fine-grained data gathering that collaborative system development can support can also enable more extensive negative coordination. This is something that designers should seek to take into account–tactfully, of course–when gathering the "positive" requirements for system usage. If people are interacting with systems in such a way as to be discreet, or to help themselves or others save face [45], that can affect how people contribute to the journeys data take through

systems, from initial data capture to analysis and accountability.

The notion of scaled stakeholders suggests that in a coordination space, we can identify possible stakeholders to model for stakeholder analysis by identifying the different coordinative units who participate in the space. This offers new potential tools for stakeholder analysis, tools that better meet the complex needs of an inter-organizational collaborative system and the coordinative space it serves. In terms of design methods, this can take the form of trying to find the "who" (the stakeholders) by first investigating the "how" (how coordination happens at different scales, and what needs and interests that connects to).

One way that an organizational stakeholder will express itself as a stakeholder in a collaborative system is by controlling how individuals act as stakeholders. Sometimes, that means reducing the collaborative value those individuals can produce. This can happen even in settings where stakeholders have goals of collaboration and transparency, and where "cosmopolitan attitudes" are common. Designers should, with care, explicitly interrogate these potentially conflicting forms of stakeholdership throughout the project, and try to learn how to help organizational stakeholders feel more confident about relaxing control in regards to their individual workers.

Designers who think of themselves as stakeholders can, if they manage this intentionally, create space for different kinds of design conversations. This can help operational and design stakeholders to come together in a more mutually inquisitive and interactive way–neither as the authoritative "expert" designers nor as contractors fulfilling client demands, but as genuine co-creators of technology with preferences and expertise that are in active play. The operational stakeholders have essentially activated the designers as stakeholders based upon prior dynamics in the coordinative space. That choice has consequences for how the coordinative space develops in the future. Speaking personally as someone who had a muddle of many different roles in the VCC, orienting myself and my design team colleagues as stakeholders from the beginning could have allowed me to create a bit more analytical clarity about my own experiences and motivations, without having to limit my participation, or sacrifice its richness.

Creating discursive framings around collaboration, both in project activities and in system elements, can also function as a kind of experiment or probe about the evolving desires and preferences of operational stakeholders. These framings are propositions about how operational stakeholders might want to shape their coordinative space, which the operational stakeholders can then respond

to. What kinds of language, and *changes* to language, are appealing and have staying power in the life of a project, can reveal how participants think about what is and isn't possible for their inter-organizational collaboration–and how that can change. Designers who want to be able to benefit from this dynamic can include explicitly discursive elements into project planning and activities: internally asking questions such as "What kinds of propositions are we trying to make with this activity?" "What are participants' reactions revealing about their values and beliefs about collaboration?" "What seems to become more or less feasible in the project during discussion?" "What levels of coordinative stakeholder are putting forth arguments and expressing their interests; how do we help to negotiate that?" Preparing these questions ahead of time can make data collection during design activities more fruitful and targeted, and potentially avoid frustrations and objections later in the project.

9.4 Closing Thoughts

The work of supporting inter-agency public service collaboration is hard, time-consuming, often ambiguous, and very rewarding. It provides a crucible for testing any number of intellectual, ethical, and methodological commitments. It can help us better understand how cities and regions adapt their operations over time, and clarify some of the decisions that can be puzzling when viewed from the "outside." It can also help us protect this critical work from attack by malicious or misguided disruptors–or more benignly, to unpack the motivations of any hidden coordinative units who shape projects but who we may not interact with directly. Its specific characteristics, while perhaps unique in some ways, also have application to other complex inter-organizational collaboration; and better understanding these similarities and differences will help us engage with shifting organizational forms and forces society creates to manage itself.

Because coordination can look like so many different things, and decay and new growth can look like so many different things, what it means to innovate shared work can also be many different things. This is part of why technosolutionist project approaches often fit so awkwardly in these kinds of settings, and (I expect) why such projects so often "fail." [2] Designers who want to help such coordinative spaces improve their operations, and become healthier and more resilient, ought

[2] https://spectrum.ieee.org/it-management-software-failures

to put more effort into understanding what innovation actually means in context.

I hope that the reader will see the ideas developed in this dissertation as an invitation. They are a starting point for observing and analyzing a fairly wide swathe of systems, policies, and interactions. They suggest scaffolds for future design methods. They also invite analysis of even longer-lived projects and infrastructures; five years is long for an HCI/CSCW research project, but at most an adolescence for the full lifespan of public service infrastructures. But fully developing them into their full applicability–and correcting their many shortcomings–will require the participation of many scholars and practitioners.

GLOSSARY

This glossary contains VCC project jargon. If there are common abbreviations associated with a term, they are given in parentheses after the term.

ACCESS DATABASE (ACCESS): A recently deprecated incident management tool at use in SDOT; a previous employee created an Access database for managing incidents, and this was in use until early 2025.

AGILE DEVELOPMENT (AGILE): An approach to software development, developed initially in the 1990s, emphasizing continuous, nimble, iterative changes over highly-structured long-term plans; and prioritizing creating working, testable software as quickly as possible.

AMAZON WEB SERVICES (AWS): A major cloud computing provider.

AZURE DEVOPS (ADO): A web-based tool for conducting Agile software development. The system allows for the creation of "user stories" and other work items to plan, discuss, and complete software development work; and to store documentation and attachments, run regression tests, and create integrations between systems. It was used collaboratively by Pariveda employees working on the VCC project and a large number of UW design team personnel.

BASIC USER USER ROLE: The user role in the VCC that grants its holder the ability to view the full VCC dashboard and active VCC incidents, and update some details of their own profile. All VCC users hold this role, as it is essential for basic system functioning.

BUSINESS WORKSTREAM (BW): A section of the VCC's project work to identify needs, constraints, and feedback on design from the "business" side of the project (managers in the functional areas where the VCC would be used).

COMPUTER-AIDED DISPATCH (CAD): A system by which urgent potential incidents (often triggered by 911 calls) are recorded by call takers. In the typical case, some information can be fed directly from the 911 call, with the 911 call taker typing in additional information from the reporter. This record can then used to dispatch the first responder agency who received notice of the potential incident. The dispatcher can usually associate a specific responder/vehicle with the incident, track their location, share and receive updated information about the issue, and deactive it once the issue is resolved.

CONCEPT OF OPERATIONS (CONOPS): A complex policy and planning document used in many systems engineering projects, intended to specify at a high level how a future system or operation will work, and its primary functional goals. In typical practice, the ConOps is prepared before system development begins in earnest; however, the VCC's ConOps was iteratively developed over several years, and a significant amount of that time overlapped with active system development.

COORDINATOR SERVICE RECORD SYSTEM (CSR): A "CAD-like" software used by King County Metro in their communication center for recording and managing issues called in by bus operators.

DASHBOARD: The "home page" of the VCC, which displayed a map on the left (with various components users can show or hide), the Integrated Dispatch Feed in the middle, and cards of active VCC incidents on the right.

DESIGN & DEVELOPMENT TEAM (D&D): The sub-team within the VCC's project management, consisting of a rotating group of UW staff and faculty and Pariveda staff, who led the definition of specific design elements of the VCC and their technical implementation, testing, and iteration.

EMERGENCY OPERATIONS CENTER (EOC): A central "command and control" communication and coordination center used during a variety of emergency situations, such as extreme weather. Typically a place where different components of a command structure can gather in one place.

INCIDENT COMMAND SYSTEM (ICS): Created by the US FEMA, "ICS is a standardized approach to the command, control, and coordination of on-scene incident management that provides a common hierarchy within which personnel from multiple organizations can be effective" (`https://www.nwcg.gov/node/1790677`).

INCIDENT COMMANDER (IC): The person with the highest authority in a given incident, responsible for making key command decisions about the management of the incident. A term typically used in the Incident Command System, the incident commander may change throughout an incident depending on a variety of factors, but the general procedure is that the first appropriate worker to arrive on scene is the IC until (and unless) a more suitable person arrives. Not all incident command processes are formal, but when there is an incident significant and inter-agency enough to trigger an ICS structure, this becomes more visible, formalized, and accountable.

INCIDENT MANAGER USER ROLE: The user role in the VCC that grants its holder the ability to create, edit, and close VCC incidents.

INCIDENT MODEL (IM): Each "VCC incident" that VCC users want to manage in the VCC has its own "incident model" page, which is created when a user clicks the Create Incident button, or auto-created when certain types of dispatch records arrive in the Feed. An IM is a collaborative page where users can provide a variety of updates on the progress of the incident, mark detours and road blockages, upload images, associated Feed dispatch events, and other relevant information. When an incident is created, users receive an email notification, and while it is "open," a card with high-level information about it appears on the VCC Dashboard. After the incident is "closed," it disappears from the Dashboard and can no longer be edited unless it is reopened.

INCIDENT RESPONSE TEAM (IRT): The section of the Washington State Department of transportation that provides key roadside assistance and traffic management services on areas where WSDOT has jurisdiction. They may help to block of sections of lanes during incidents,

move disabled vehicles to the side of the road, and other services. While they are organized under WSDOT, they are primarily dispatched by WSP and often assist WSP.

INFORMATION TECHNOLOGY DEPARTMENT (ITD): WSDOT's IT organization.

INTEGRATED DISPATCH FEED (IDF; "THE FEED"): A section of the VCC's dashboard, and also on its own dedicated page, that brings together active and recent CAD records from the VCC's source systems (SFD, SPD, WSP, and KCM) in a tabular, chronological view.

INTELLIGENT TRANSPORTATION SYSTEM (ITS): A term that refers to a wide variety of technologies used to manage transportation systems. They can include sensors that detect traffic volumes, algorithms that adjust the timing of traffic signals, and other such systems.

JOINT INFORMATION CENTER (JIC): Similar to an EOC but with more focus on public information sharing.

KEY AGENCY REPRESENTATIVES: Designated operational stakeholders who were meant to be important points of contact for their agency.

KING COUNTY METRO TRANSIT (KCM, KC METRO): The King County agency that runs the King County Metro bus service, and operates some Link Light Rail services on behalf of Sound Transit.

MINIMUM VIABLE PRODUCT (MVP): A term often used in Agile software development referring to the first iteration of a product that has sufficient stability, usability, and feature completeness to be used by real or realistic users for functions identifiably similar to the product's requirements. What actually counted as an MVP for the VCC project, which had certain regulatory commitments around its open use, was an ongoing subject of discussion.

MOBILITY STRATEGIES: A section of the VCC Incident Model, where congestion management personnel can coordinate on road management tasks such as activating highway overhead signs.

MOTOROLA: The vendor for some of the popular integrated radio systems used by various members of the VCC's operational community. Users often call the entire screen and tools surrounding simply as "Motorola."

NATIONAL INCIDENT MANAGEMENT SYSTEM (NIMS): Created by US Department of Homeland Security, NIMS is a framework for incident management. Closely associated with ICS but broader in scope.

NORTHWEST SEAPORT ALLIANCE (NWSA): An organization focused on cargo at the Seattle and Tacoma harbors.

OFFICE OF EMERGENCY MANAGEMENT (OEM): The City of Seattle Emergency Management office, which has facilities and procedures for handling large-scale emergencies. Even severe traffic incidents do not usually rise to the level of needing OEM engagement, but OEM was frequently a peripheral partner in VCC and SAJOG activities.

OFFICE OF THE CHIEF INFORMATION OFFICER (OCIO): The office of the WSDOT's information security branch.

PARIVEDA SOLUTIONS (PARIVEDA): A software design and development consultancy, with particular experience in Amazon Web Services integrations, who led the technical design and implementation of the VCC.

PERIMETER: A physical zone around an incident, defining some sort of functional boundary between the incident and the outside world. There can be more than one perimeter associated with an incident (for example, there may be an investigation perimeter controlled by law enforcement, to protect evidence, as well as a safety perimeter, often controlled by the fire department).

POPULATION MOVEMENT (POPMO): A term for the kinds of public outreach and media management work, often done by Public Information Officers, incorporated into the VCC's col-

laboration, as it involved "moving the population" via influencing their movements during incidents.

PORT OF SEATTLE (THE PORT): A "special purpose government" entity focused on security, shipping, and commerce at the Seattle harbor, as well as the Seattle International Airport.

PREPLANNED PLAYS (PLAYS): A proposed feature of the VCC (which was ultimately not developed), which would function as rough templates of common major incident types.

PUBLIC DATA REQUEST (PDR): The mechanism by which members of the public can request copies of public data. What counts as public data susceptible to PDRs depends somewhat on context and jurisdiction.

PUBLIC INFORMATION OFFICER (PIO): A professional whose primary responsibility is communicating with the public about important issues an agency or other public-facing organization is working on. Often, an agency's PIO will write key social media posts and blogs about incidents or projects, attend press briefings, and prepare communications to be sent to high-level executives. These communications can relate both to incidents and major planned work.

RECORDS MANAGEMENT: The section of the VCC (and related efforts/capabilities) where data about closed incidents is temporarily stored. This includes each note, file, field update, ID of related dispatch events, and the like. Each time such an incident record is finalized, it is emailed out to records management personnel at each partner agency (and such records management personnel do not need to be VCC users; this is a separate mailing list) to store and manage according to their agency's own procedures.

RECORDS MANAGER: The VCC user role that can access the Records Management section of the site.

REGRESSION TESTING: Testing and validation of software in progress against specific functional benchmarks.

RETROSPECTIVES (RETRO): A common "ritual" of Agile development, where the development team gathers on some interval–often one month–to review recent work and consider how to continue improving the way work is done.

SDOT RESPONSE TEAM (SRT): The section of the Seattle Department of Transportation that provides key roadside assistance and traffic management services on areas where SDOT has jurisdiction. They may help to block of sections of lanes during incidents, move disabled vehicles to the side of the road, and other services.

SEATTLE AREA JOINT OPERATIONS GROUP (SAJOG): Group of agencies and organizations doing work related to major incident management in Seattle; convened in 2018 after a series of severe incidents were found not be handled as well as they should. The organization that worked with UW and Pariveda to create the VCC. VCC user membership and SAJOG have significant, but not perfect, overlap.

SEATTLE DEPARTMENT OF TRANSPORTATION (SDOT): The Seattle city agency that has primary jurisdiction on city road structures and infrastructures.

SEATTLE FIRE DEPARTMENT (SFD): The fire department with primary jurisdiction in and near Seattle.

SEATTLE IT: Central City of Seattle IT, which serves many different groups and agencies under the City of Seattle umbrella. Seattle was undergoing an IT centralization effort during the VCC project; had the project taken place a few years earlier, for example, the VCC project would have had to work separately with Seattle Fire IT and Seattle Police IT to obtain the two Seattle CAD feeds.

SECURE ACCESS WASHINGTON (SAW): An authentication tool offered by the State of Washington which allows Washington residents to securely access a variety of state sources. It was also chosen as the authentication/identity provider for the VCC, so all VCC users must multi-factor authenticate with SAW when logging into the VCC.

SITUATION MAP : The section of the VCC's Dashboard (and with each individual Incident Model) which shows a variety of map-based information to VCC users. Records from the Dispatch Feed that have geolocation information are plotted automatically, as are VCC incidents. In addition, there are toggles for real-time traffic information, construction project information, and city and state traffic cameras.

SITUATIONAL AWARENESS (SA): A term, used in various ways, to denote the general capability of knowing what is going on with a situation, and being able to obtain and make sense of changing information related to that situation.

SOUND TRANSIT (ST): A regional (the Puget Sound area, extending into Snohomish and Pierce counties) transit authority that owns the Link Light Rail, the Sounder commuter train, and some regional buses.

STEERING COMMITTEE (STEERCO; STEERCOM): The Steering Committee for the VCC project, whose membership did shift somewhat throughout the project but generally consisted of a small subset of SAJOG's operational stakeholders.

SYSTEMS ENGINEERING (SE): A very popular and common design, engineering, and project management methodology. Developed beginning after WWII, it is commonly used in one form or another in large complex projects, including infrastructure and government projects.

TECHNICAL SOLUTIONS WORKSTREAM (TSW, TECHNICAL SOLUTIONS): A section of the VCC's project work regarding the fundamental technical design aspects, including setting up feed integrations, writing software, and complying with data security requirements.

THEME (A-G) : A grouping of software development work used in the VCC project.

TRAFFIC INCIDENT MANAGEMENT/CONGESTION MANAGEMENT (TIM/CM): The general term describing the work of managing traffic incidents and significant congestion, using physical work on scene (such as physically blocking lanes or moving disabled vehicles to the side of the road), manipulating of ITS devices, coordination and messaging, and related tasks.

TRAFFIC OPERATIONS CENTER (TOC): The control room operated by SDOT, tasked with monitoring city roadways (primarily via trafifc cameras, social media, SFD and SPD dispatch, and radio channels), updating the public on traffic-impacting incidents in or near SDOT's jurisdiction, coordinating with SRT's dispatcher, and allowing traffic engineers to make some adjustments to signal timing and related traffic engineering tasks.

TRAIN THE TRAINER : A series of training exercises and related materials created by the VCC's User Adoption team a few months prior to the VCC's operational deployment. The idea was to recruit a small number of future users who would gain early access and training in the VCC, so that when the VCC was deployed, they would be the first line of support and advocacy of the VCC at their own agency.

TRANSPORTATION CONTROL CENTER (TCC): The control room operated by King County Metro Transit, tasked with monitoring and adjusting the operations of KCM's buses, including frequent real-time communication with bus drivers, and handling mechanical, safety, and technical issues, often in coordination with other agencies.

TRANSPORTATION MANAGEMENT CENTER (TMC): The control room operated by WSDOT, tasked with monitoring state-managed roadways and facilities (primarily via trafifc cameras, social media, WSP dispatch, radio channels, and sensors), updating the public on traffic-impacting incidents in or near WSDOT's jurisdiction, coordinating with IRT and WSP, and making real-time and planned changes to ITS devices such as tolling algorithms and ramp meters.

TRANSPORTATION MANAGEMENT SYSTEM (TMS): A WSDOT-internal incident management system, with integrations to other WSDOT systems and some overlap with the VCC.

USE, FEEDBACK, REFINE (UFR): The term coined by the VCC's project team to refer to the user acceptance testing activities it conducted.

USER STORY (STORY): The main unit of work in Agile software development. Each one is typically written from the perspective of a kind of user and a desire or need they might have, which the system under development can help them do ("As a [Type of user] I want to [complete

some task in the system under development] so I can [accomplish some goal]"). Stories are typically assigned numbers of "points" based on how much effort they're expected to require to complete.

VARIABLE MESSAGE SIGN/DIRECT MESSAGE SIGN (VMS/DMS): Signs viewable by the public–typically overhead on highways–to advise them on relevant transportation conditions. VMSs often advise drivers on a major highway of severe congestion or major incidents they may encounter.

VIRTUAL COORDINATION CENTER (VCC): Web-based traffic incident and congestion management used by relevant stakeholders in the Seattle area. The project which is the empirical focus of the dissertation.

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION (WSDOT): The Washington state agency that has primary jurisdiction on state-managed road structures and infrastructures (including both state roads and interstates).

WASHINGTON STATE PATROL (WSP): The law enforcement agency with primary jurisdiction on and near state and federal roadways in Washington.

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Appendix A

INTERVIEW PROTOCOL FOR 2025 INTERVIEWS

A.1 Preamble

1. Hi [name]. Thanks so much for agreeing to talk with me today. [Introduce myself if they do not already know me.]

2. In this interview, we're first going to talk about the work you do in general related to traffic congestion or incident management [design stakeholders: the general design work you did for the VCC]. Then we will talk more specifically about your experiences [using the VCC] [working on the VCC project and your views on it].

3. From talking with you and several others who have a variety of relationships to the VCC, I'm hoping to learn more about how different agencies, operational communities, and other stakeholders have adapted how they understand and use the variety of technology systems they use in their work.

4. Have you had a chance to look over the consent form?

5. I want to remind you that you can end the interview at any time and don't have to answer any questions you don't want to.

6. Are you okay with this interview being recorded? As a reminder, only I will have access to this recording, and any research that's published based on it will obscure your identity by default. [Reminder that audio recording is also acceptable, as is a notes-only (non-recorded) interview.] [If they say no, thank them and end the recording.]

7. Do you have any questions for me at this point?

A.2 Warmup Questions

1. Can you tell me your current job title at [agency or organization] and how long you've been in it? [Alternative for design stakeholders: What is/was your job title at Pariveda/UW and how long have you been/were you in it?]

2. What kind of work do you do on a typical work day relating to TIM, CM, or communicating with the public–that is, one without a major incident? [Alternate version for design team participants: When you were working on the VCC, what was a typical week of VCC-related work like for you?] (asking this way because there was more of a weekly rhythm)

3. How is that different on a day with a major incident? [If design participant: skip]

A.3 Design Stakeholders Only

1. When did you first learn about the VCC project?

    - What was your understanding of the goals of the project at first?
    - How did that change while you were on the project?

2. Thinking back to when the VCC was being planned and developed, the team (Pariveda and UW design and development members) used a number of design approaches and activities. For example, we used Agile-style design sprints, user stories, user acceptance testing, and structured design workshops. What do you recall about how these methods were adapted to the unique characteristics of the VCC project?

    - Were there any adaptations–like adjusting schedules or providing more structure to requests–we made that you thought were too significant to be able to yield their full benefit?

3. What did the design team do that you think most effectively helped figure out "stakeholder needs"?

- Similarly, what attempts were made to determine stakeholder needs that didn't work as well as hoped?

4. Of course, facilitating and innovating collaboration was a major goal of the VCC. But "collaboration" is a pretty vague concept. What roles did the design team play in helping the operational stakeholders think through what collaboration meant to them in the VCC system and project? [Add clarifications if needed]

   - What differences did you see in how Pariveda and the UW team approached this topic, if any?
   - (If not addressed) How do you think we did in terms of striking that balance between revealing what the operational stakeholders wanted and advancing our own design goals?
   - How did you see the design/development strategies we took changing through the life of the project? [Followup: What do you think spurred those changes?]

5. One early subproject in the VCC's development was creating the Integrated Dispatch Feed and specifying what a "dispatch event" was. What do you think were the most impactful aspects of designing the dispatch feed for the overall success of the project?

6. The VCC is a shared system, so it had to fit into a wide variety of organizational and work environments, including sharing device space and users' attention with other systems.

   - Which of these systems do you remember as being most significant for their users?
   - From your perspective, what were the most important impacts of the agencies' other IT systems on the trajectory of the VCC's development?

7. How did the team handle the variety of stakeholders' beliefs about jurisdictional issues when designing VCC user roles and permission sets?

   - How did the team handle the variety of stakeholders' beliefs about chain of command when designing VCC user roles and permission sets?

- Did you perceive any difference in approach between the operational stakeholders and the design team about how permissive the system should be?

8. Over the VCC project, we iterated multiple governance structures, like the Steering Committee, Key Agency Reps, and the functional teams. We also developed a variety of policy documents like the SAJOG charter and ConOps. In terms of the policy documents and governance structures that were created to help manage the VCC project and move it forward, which do you think were most effective?

    - Why?
    - Which governance and policy approaches do you think didn't work as well?

9. If you were to engage in the VCC project again with the full benefits of hindsight, how would you approach it differently? [May require several followups as it's a very substantive question]

10. BONUS Question if time permits: Work is currently underway to expand the VCC to more areas, perhaps even statewide. Have you heard anything about this expansion?

    - Based on your experience developing the VCC, what do you see as the most important challenge that will need to be addressed for this expansion to be successful?

A.4 Operational Stakeholders: Questions about VCC History and Use

1. How and when did you first learn about the VCC? [Clarify if needed: this can include knowing about it before it was called that; i.e., in the very early design phases]

2. Overall, how would you describe your current use of the VCC?

    - How do you feel like that use has changed over time?

3. Who do you think fits within the VCC's broader operational community?

4. What are the primary communications or IT systems you use to do your [Traffic management/congestion management/public communication] work?

5. Thinking about the other communications or IT systems you use to do your [Traffic management/congestion management/public communication] work, how does the VCC currently fit into those systems?

    - Followup if necessary: where is there overlap between the VCC and those other systems, in terms of what information or functionality they provide you?
    - Followup if necessary: probing daily vs. larger incidents

6. Can you tell me about a time you saw something someone else did in the VCC–such as entering data in an incident model field or creating a mobility strategy–that when you saw it, you weren't sure what it meant?

    - Did you figure it out eventually?
    - Now that you've had time to see how people at other agencies are inputting data into the VCC, has that helped you understand the way other agencies are working?

7. How, if at all, has your understanding of what an 'incident' is changed since you've started engaging with the VCC?

8. Through the project, there have been different perspectives on which users should be allowed to various take actions in the VCC, like creating a VCC incident, adding notes or files, or editing another user's permissions. Has your thinking on this changed at all since you first started engaging with the VCC?

9. If you had an IT issue with the VCC, who would you contact first?

10. Now that you're more familiar with the VCC in terms of what it can do and what it can't, what's one change you'd most like to see in it?

A.5 Operational Stakeholders: Scenario Walkthrough

(Put most of the text of this question for them in the Zoom chat so they can refer to the details without having to remember them.). For the last main section of the interview, I'd like to switch

gears a bit. We're now going to work through a potential major incident scenario. If you were a part of the VCC's design workshops or have read the VCC ConOps, you might remember the "operational scenarios" we created. These were fictitious incident scenarios that were used to explore and illustrate how the TIM-CM community could collaborate. So this should go pretty similarly to that. Let's imagine you're working at 4pm on a cold Thursday. It's raining lightly and might start raining harder, or maybe even snow. Near the Convention Center on I5 NB, a large commercial vehicle loses control and starts to jackknife across the freeway. It crashes, striking multiple additional vehicles and releasing some kind of substance, blocking all NB lanes but part of lane 1. [Give them a moment to think.] I'm going to ask you a few questions about how this incident might play out, if it were to happen *in the near future*, say within the next year.

1. How would you most likely find out about this incident?

2. If VCC not explicitly mentioned, ask when information coming from the VCC would first enter their awareness

3. What kinds of decisions and analysis would you likely have to make early on in the incident?

4. What types of changes in the situation would you be on the lookout for?

    - How would you find out about them?

5. Who would you most likely collaborate with at different stages of the incident?

    - How would that collaboration differ agency to agency?

6. What kinds of impacts do you think the incident might have on other people in the VCC's broad operational community?

7. What factors, including but not limited to optimal VCC usage, would make this incident go more successfully?

8. What kinds of analysis and reporting would [your agency/workgroup] do once this incident was over?

9. Are there any other aspects of successfully managing a major incident like this I should know about?

10. Followups if needed regarding how long it might take, what additional complications would be likely to arise, what sorts of tradeoffs might be needed, and how their own agency or workgroup would collect data and perform followups afterward.

A.6 Closing (All Participants)

Thank you so much for your time today–it was really enlightening and, at least for me, really enjoyable.

1. The last thing I will ask you is whether there was anything you'd like to share that didn't come up in the interview, but that you think it's important for me to know?

2. Okay, great. And do you have any questions for me, before we end the interview?

3. Thanks again so much! And if you think of anything else later you'd like to add or amend, just email me and I'll include it.

Appendix B

FINAL CODEBOOK

Below is the final codebook used in the dissertation, after multiple rounds of analysis of the original corpus, and incorporation of new findings from the 2025 interviews.

Theme	Code
Effects of particular system configurations on different sorts of work	Different types of glanceability
	Acceptability and actionability of VCC data
	Tensions between common language and possible inefficiencies
	How VCC could impact other systems or technology planning
	Interface and device sharing with other systems
	Nascency of VCC practice and user adaptation
Reimagining and responsibilizing the “who”	What parts of VCC touch operational relationships
	Different types of workers and trust models
	Protecting workers from demands of VCC
	Designers building VCC roles and work structures
Development and use of systems over time, space, and communities	Intra-agency decay and new growth
	Partial system and information access
	Other partial inter-agency projects
	Design storytelling based on current state
	Ontologies, counterfactuals, and prefiguration
	Designers constructing notion of dispatch event
Historicizing, reifying, problematizing, and iterating collaboration	Imbrications of interagency SA with new tool
	Patterns of collaboration including norms and historical relationships
	Negative or antagonistic coordination
	Attempts to “design” the collaboration
Formulating and contesting boundaries of data and analysis	Analyzing signals from other workgroups
	Items visibly crossing jurisdictional boundaries
	Operational and system-based jurisdiction models
	Ontological and temporal boundaries of incidents
	Beliefs about others’ work, needs, or preferences

Table B.1: Codebook