Communication Chains: A Methodology for Assessing the Effects of the Internet on Communication and Travel

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ALTHOUGH numerous researchers have investigated the impact on travel of specific telecommunications applications like telecommuting, only rarely has a broader look at the impact of electronic communications on multiple communications media, including travel, been attempted. This is no doubt due in part to the measurement challenges associated with such an attempt. Time-use diaries, activity diaries, or communication logs can provide opportunities for cross-sectional analysis, typically at a single point (or small interval) of time. However, these tools generally do not identify the chain of communication events cascading from a specific message, and thus are unable to capture behavioral linkages between events. Thus, for example, if a cross-sectional study using such a tool finds that greater Internet use is associated with more travel, it has not been established that the Internet use *caused* the travel; a third-party variable such as income, or a gregarious or variety-seeking personality, may be responsible for both effects separately. On the other hand, following communication chains in a precise and quantifiable way is a daunting task for both the researcher and the respondent.

Nie et al.
Viswanathan and Goulias
Mokhtarian and Meenakshisundaram

Robinson et al.

The methodology proposed in this study offers a practical middle ground between no data and perfect data on causal

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linkages. Specifically, for a given Internet activity, we simply ask the respondent to identify its causal antecedent and its likely communication consequences, by checking off the appropriate responses from a list. Obviously, by sacrificing precision and detail we lose the ability to quantify those consequences (e.g., in terms of miles of travel generated or substituted). However, we argue that the qualitative view of causal chains provided by this approach can offer valuable insights not possible from single cross-sectional studies alone.

We analyze the relative strengths of effects of a given Internet activity in three ways. Using a 1994 sample of 148 early Internet adopters to illustrate the application of the methodology, we first tabulate the total presence, within the sample, of specific types of effects, to assess the net effect of Internet activities on other communication media. Second, we tabulate the frequency with which specific combinations of effects, or "pattern vectors," occur in the sample. Finally, we use cluster analysis to identify latent types of communication chains having relatively similar causal relationships between Internet activities and other media.

To establish a theoretical background and context for this study, we briefly summarize the relevant literature and develop a conceptual framework for understanding interactions among communications media. After introducing the survey instrument and methods of analysis, we apply the proposed methodology and discuss key empirical findings.

Review of Some Relevant Literature

Telecommunications and transportation might each be considered subtypes of communication in general. This typology implicitly involves a re-classification of transportation, proposed long ago by a sociologist, C. H. Cooley, and echoed more recently by transportation researchers like Salomon and others. One might equally argue that telecommunications could be re-classified as transportation; for example, Mokhtarian asserts that "all communications require transportation [of a person, an object, or a signal] in order to occur." These are essentially different formulations of a single paradigm that transportation and communications are in some sense the same; they are a duality.

Salomon 1986

Mokhtarian 1990

Perhaps because of the increasing recognition of this duality, or perhaps in response to the emergence of new communications technologies over the last forty years, the relationship between

telecommunications and transportation has been discussed repeatedly in the transportation and (less often) communication literatures. Mokhtarian and Salomon offer a useful summary of conceptual progress and research to date; some important elements of this discussion are summarized below.

Albertson
Nilles et al.
Owen

The thrust of much early inquiry into the connections between telecommunications and transportation emphasized the potential for cross-medium substitution. Primarily, the form of substitution of greatest interest has been the replacement of trips with telecommunications activity, although substitution in the reverse direction is also possible. Transportation planners interested in congestion management, especially, have hoped that the increased availability of telecommunications technologies would produce reductions in travel for work, shopping, and other purposes.

Salomon 1986

However, substitution is clearly not the only possible interaction between communication media. The option of neutrality (or no significant interaction) must be recognized, in addition to a myriad of other interaction types including: 1) modification, whereby one medium alters the form or pattern of another's use; 2) enhancement, whereby use of one medium increases the intensity of another's use; 3) operational efficiency, whereby one mode is used to contribute to the efficiency of the other; and 4) indirect or long-term interaction, such as the effect of telecommunications on land use and thus indirectly on transportation. Accordingly, the belief that advanced telecommunications systems will substitute for or reduce travel has increasingly been augmented by the recognition that other effects, such as generation and modification of travel, may also occur. This hypothesis of complementarity appeared early in the academic literature, although more attention has been paid to the potential for substitution, at least until recently.

Mokhtarian 1990

Albertson

Mokhtarian 2003
Mokhtarian and Salomon
Salomon 1986

Aggregate empirical studies indicate that the relationship between telecommunications and transportation varies by economic sector. Plaut found complementarity in industrial demand for transportation and telecommunications, while in the arena of consumer (household) demand, Selvanathan and Selvanathan found transportation and telecommunications to be substitutes. Further confirmation for the latter finding is supplied by recent time-series analyses, which indicate that telecommuting in particular does reduce vehicle-miles-traveled, albeit only modestly. However, structural equation models of aggregate time series data for the United States (including both industrial and

Choo et al.

consumer demand) have found complementarity to be the dominant impact.

Choo and Mokhtarian, "Telecommunications. . ." Choo and Mokhtarian, "Does Telecommunications. . ."

Most disaggregate empirical studies of the relationships between telecommunications and travel focus on the effects of specific applications, such as telecommuting and videoconferencing, on travel. The available studies of telecommuting to date unanimously report substantial net reductions in individual travel for the short term, although several of them caution that system-level effects were negligible at the time of study and could remain so for quite some time. At least one study of teleconferencing documented a net increase in travel, due to more people traveling (albeit shorter distances per person) to the videoconference location than would have gone to the more distant central meeting location. Mokhtarian and Meenakshisundaram, analyzing different data from essentially the same sample as that used in the present study, developed a system of structural equations to represent the quantity of communications of a given type at a given time as a function of the quantity of communications by each of the various types at an earlier time, elapsed time, and sociodemographic variables. This more comprehensive disaggregate approach, capturing temporal, if not causal, relationships between media, yielded evidence of complementarity between different types of communication.

Hamer et al.
Henderson and Mokhtarian
Koenig et al.
Mokhtarian and Varma

Mokhtarian 1988

Several other studies have addressed the role of less novel communications technologies. One such study, by Claisse and Rowe, is particularly interesting because their approach is similar to (albeit simpler than) that of the current effort. Categorizing telephone activity in terms of whether a call was reported to "induce" a trip, substitute for a trip, or influence the particulars of a trip, and analyzing net volumes within these categories, Claisse and Rowe reported a net reduction of 6 percent of all urban trips resulting from telephone use. As Handy and Mokhtarian point out, however, the study is limited by its focus on residential phone habits, its exclusion of any incoming calls and the lack of an activity-based approach, emphasizing a single event rather than a chain of events. It is also impossible to tell whether there is a net reduction in distance traveled, since the reported induced trips might have been longer than the more numerous substituted trips.

In another relevant study, Moore and Jovanis modeled communication medium choice in business contexts. Analyzing logit models estimated using data from stated-preference surveys of employees in two companies, they found that communications

medium choice depended significantly upon the context of communication. In particular, respondents were likelier to prefer e-mail for simple messages sent within a company than for complex or inter-organizational communications. While Moore and Jovanis did not explicitly consider substitution for travel, their work is especially noteworthy for its conceptual contributions to the study of communications medium choice and as an early examination of the role of electronic mail in individuals' choice sets.

Like the Moore and Jovanis study, our study attempts to measure interactions between communications media; however, they limit the scope of their study to medium choice for a single communication, whereas ours addresses choices with respect to previous and subsequent activities as well. Specifically, we address the question of whether communications medium choices are concatenated in ways that influence the overall volume of particular communication types. The conceptual foundations of this inquiry are developed further in the next section.

Conceptual Framework, Assumptions, and Hypotheses

This study is based upon an activity-based approach to communications, where an activity is described as a reaction to one or more stimuli. According to Salomon, these stimuli are, in most cases, needs for fulfillment at some psychophysical level, first realized at a subconscious level, and later translated into a cognizable purpose. Activities could be prompted by these stimuli externally (as when we return a friend's phone call) or internally (as when we spontaneously decide to call a friend to whom we have not spoken in a while).

Salomon 1985

Maslow

In this paper, we focus on activities involving communication of words in some way ("communications activities"), in particular pivoting on activities using the Davis Community Network (DCN), a communications network created in 1994 to offer Internet access and community information to residents of Davis, California. (The network is accessible at <www.dcn.org> or <www.dcn.davis.ca.us> although, naturally, it has changed greatly since its inception.) Each stimulus is associated with a set of possible alternative media that could be used to accomplish the desired communications activity. Each of these media has some unique utility, given individual characteristics, activity characteristics, media characteristics, and situational constraints.

Moore and Jovanis

For each individual's activity stimulus, then, either no media are feasible (i.e., the medium choice set is empty) and the activity does not occur, or some medium out of one or more feasible media has maximum utility and is chosen. Each available medium is therefore associated with some set of activity demands for which its utility is maximum. An increasing share of activity demands satisfied by (for example) the DCN could, therefore, be created either by increasing the dominance of DCN utility over other media or by increasing the volume of actualized activity demands for which DCN utility is dominant, including activity demands for which the DCN is the only media option.

It is furthermore entirely conceivable that the external stimulus for a communications activity could be associated with another communication. In this manner, activities can affect other activities by generating them, eliminating them, or modifying their details. When we say that a DCN activity is "generated" by another activity, we mean that some other activity presents the stimulus for a demand which may best be satisfied using the DCN. When we say that some activity is "eliminated" by a DCN activity, we mean that the chosen (and hence maximum-utility) DCN activity satisfies a demand which, in the absence of the DCN option, would have been satisfied by some other option. When this elimination occurs contemporaneously (i.e., when the alternative would have occurred at the time at which the DCN activity occurred), we refer to this relationship as "replacement."

Finally, information obtained or exchanged using the Internet could affect the planning, monetary, or time costs of some future trip, potentially resulting in different timing, destination, route, or transportation mode being chosen. In this case, although no activity is eliminated and no new activities are necessarily generated by the use of the DCN, a previously-planned trip is "modified" by the use of DCN in activity planning.

Internet use and travel differ broadly in terms of media characteristics. The information that is available on the Internet can usually be obtained much more quickly via the Internet than via some travel-based alternative. These differences of speed may be offset by differences in content depth, and especially in 1994, the Internet mostly offered text and limited graphics (depending on browser and connection speed). In contrast, face-to-face communications, enabled by travel, generally offer full sensory detail and high interactivity, suggesting that

travel-enabled communication and Internet use are ideally suited for different kinds of activities. This makes it difficult to declare Internet use and travel to be complete substitutes in all—or even in many—instances. Furthermore, many activities made possible by the Internet would simply be infeasible if pursued via any other medium, and, therefore, represent demands that would likely go unsatisfied in its absence.

Therefore, while the choice of medium remains rooted in the relative utility of that medium for a particular communication activity (a topic not directly addressed here), different activities with different associated optimal media could well be behaviorally linked in such a manner as to influence the overall volume of communications in a given medium. These "communications chains" have rarely, if ever, been directly observed in a disaggregate study. The methodology proposed here offers a means to observe and evaluate the relative strengths of medium interaction effects, and in so doing, empirically investigate how the emergence of new telecommunications activities influences engagement in different forms of communication, including travel. The following section describes the methodology used to accomplish these aims.

Methodology

Sample and Survey Instruments

This investigation takes for its empirical application the Davis Community Network (DCN) mentioned earlier. Implementation and evaluation of the DCN project was funded by the California Department of Transportation (Caltrans), with the primary goal of evaluating the travel behavior implications of this emerging technology.

In 1994, Davis, California was a town of about 45,000 people, surrounded by agricultural land. Then, as now, the University of California at Davis dominated the local population and employment, although a large portion of its residents commuted to state jobs in the capital of Sacramento about 15 miles away. Dial-up Internet access was a relatively rare service at the time. Among urban American households with income exceeding $75,000, fewer than 40 percent owned both a computer and a modem. Furthermore, as Benjamin Compaine notes in his forward to *Digital Divide: Facing a Crisis or Creating a Myth?*, "PCs with modems were for the most part still used to connect

NTIA

to proprietary online services, such as CompuServe, Prodigy, and America Online." The DCN data, therefore, provide an unusually detailed picture of the communications choices of early U.S. adopters of the Internet.

Participants in the DCN evaluation completed three kinds of survey instruments, of which one, the *Communications/ Travel Log*, is not discussed further here (see Mokhtarian and Meenakshisundaram for an analysis using that instrument, and Copher et al. for description and analysis of a similar type of instrument). The two other instruments were the *Background Survey* and the *Activity Diary.* The *Background Survey* was designed to obtain general information on user characteristics, some of which are presented here.

Of the 273 respondents to the *Background Survey*, 42.1 percent were female. Twenty-three percent of the sample was 25 to 34 years old, 29 percent were 35 to 44, and a similar proportion were 45 to 54 years old. About 27 percent had household incomes over $75,000; about 17 percent had incomes between $55,000 and $75,000; and a little over 30 percent had household incomes between $35,000 and $55,000. Nearly all (97 percent) of the sample had computers at home; 86 percent had more than four years of experience with personal computers; 81 percent reported using computers *primarily* for work activities; and about half of the respondents had seldom or never used online services. Thus, not surprisingly, given the characteristics of Davis and the nature of the study, the sample is relatively young, affluent, and computer-literate.

While the *Background Survey* provided information on the characteristics of the respondents, the *Activity Diary* provided information on the various effects of using the DCN. Approximately half of the sample was randomly selected to receive the survey through a mail-back paper version, while the other half received an electronic version of the diary over the Internet. To maximize the response rate, respondents were allowed to request and receive the other form instead, but relatively few did so. Seventy-one people completed the paper version of the *Activity Diary* and 77 people responded to the computer version of the diary. In the current study, however, responses are pooled without regard to survey type.

Each diary requested information on up to five uses of the DCN ("communication activity descriptions"). The 148 respondents to the *Activity Diary* described a total of 636 activities, averaging 4.3 descriptions per person. For each DCN

communication, the respondent provided information on both the current activity she was engaged in and the expected effects of that activity with respect to further communications. Activities were broadly divided into four categories depending on the associated media indicated by the respondent. These categories were: in-person communication (i.e., face-to-face interaction); electronic communication (including telephone calls, faxes, electronic mail, and other online options); communication via object delivery (such as mailing or picking up print documents or computer diskettes); and travel.

Measures of in-person communication and travel are related, although not identical. At small time scales, inter-personal communication can occur among those within earshot without requiring travel, although at larger time scales, in-person communication cannot be accomplished without travel, except in the most extreme cases of mobility restriction. Conversely, in some instances travel can occur for purposes other than in-person communication. Therefore, while in many cases travel and in-person communication will no doubt accompany each other, our instrument measures these activities separately, to reflect their potentially distinct roles in the respondents' choices.

Questions regarding the current communication concerned the *initiator* of the communication (survey respondent or somebody else), the *purpose* of the communication (work, social/entertainment, school, etc.), the *nature* of the communication (sent/received/requested information, conducted a transaction, etc.) and the *antecedents* of the activity (whether any previous activities prompted the current communication and, if so, the details of those prompting activities). The respondents were also asked to report which *alternative* media, if any, could have been used to carry out the activity, in the hypothetical absence of DCN availability.

Another set of questions concerned *future expected effects* of three types: *generation of additional* activities, *elimination of previously planned* activities, and *modification of previously planned* activities. For each of these questions the respondent was first asked whether any such effects were anticipated. If so, details were solicited regarding the expected effects, including information on the type of activity affected (in-person, electronic, etc.). Finally, respondents were asked to indicate *why DCN was chosen* for the current activity, and the *advantages and disadvantages* of using DCN as the communication medium for the activity described. All of these questions were essentially close-ended,

i.e., requiring the respondent simply to check off the appropriate answers. In addition, we invited brief open-ended elaborations on all but the first three questions (initiator, purpose, and nature).

The vast majority (over 81 percent) of the 636 communication activities reported were respondent-initiated. Consistent with other studies, e-mail was the dominant application, used in nearly 64 percent of communications. (See Table 1.) The distribution of stated purposes of the communication reveals that respondents used the system for work-related activities more than for any other purpose. However, respondents also substantially used the system for social/entertainment purposes, browsing, and hobbies. (See Table 2.)

When asked, "*What did you do during the current communication?*" respondents answered "*sent/received/requested information*" for 477 (75 percent) of the 636 communication activities, "*conversed*" for 153 (24.01 percent) descriptions, and "*conducted a transaction*" in only five (0.79 percent) cases. The latter two percentages would doubtless be higher today than at the time of the DCN evaluation, because of the growth in the total number of people online and the major improvements in Internet transactions security.

Analysis Methodology

The data used in the analyses reported here derive from responses to the *Activity Diary* instrument. As indicated above, in addition to describing current activities, the respondents also gave the details of any antecedents ("parents") of current activities and any expected effects —"offspring" activities that might be generated,

TABLE 1
DCN Applications

Application Used	*Frequency*	*%*
E-mail	405	63.68
WWW	86	13.52
Newsgroups	73	11.48
File download (FTP)	38	5.97
Search engine (Gopher)	23	3.62
Hypertext browser (Lynx)	8	1.26
Chat (IRC)	1	0.16
Miscellaneous	2	0.31
Total	636	100

TABLE 2
Distribution of Activities by Purpose

Purpose	*Frequency*	*%*
Work	206	32.39
Social/Entertainment	143	22.48
Browsing	102	16.04
Hobby	69	10.85
Volunteer work	59	9.28
Traveling	14	2.20
Shopping	12	1.89
School	12	1.89
Other	19	2.99
Total	636	100

modified, or eliminated by the current activity. Each activity was, therefore, tagged not only by its own characteristics, but also by whether it was prompted by other activities, and by the media of the activities that it was anticipated to generate, modify, or eliminate. Given this information, we first examined the overall antecedents and effects of the DCN communications studied, by simply reviewing the total number of activities having antecedents and effects in each category. We next sought to identify *patterns* of cause and effect, linking communications using different media. This was accomplished by analyzing the frequency with which combinations of causes and effects occurred in the sample, via either simple pattern tabulation (counting the frequency of each distinct pattern) or cluster analysis.

Cluster analysis is an algorithmic procedure by which n distinct cases or objects, each measured with respect to the same p properties, are grouped into some number of classes (clusters) such that the members of each cluster are more similar to each other than to the members of other clusters. In this particular context, this means that the activities belonging to a given cluster would share relatively similar causal relationships to other types of activities. Therefore, the cluster represents a kind of "latent type" of communication chain, not necessarily directly observable in any individual survey response, but nonetheless representative of an underlying pattern of interaction among media.

Almost all clustering procedures involve three important steps, each closely related to the other: 1) choice of properties or dimensions on which the data set is to be clustered; 2) choice of a similarity, or dissimilarity, measure; and 3) choice of clustering

algorithm. In our context, the clustering dimensions to be used are subsets or combinations of the properties described in the preceding sections: *prior* prompting by another activity in some medium (in-person, electronic, object, or travel); *contemporaneous* interchangeability with (or replacement of) an activity in some medium; and generation, elimination, or modification of *future* activities of various media. Various considerations informed the selection of several subsets of these dimensions for detailed study:

1. Simple tabulations (see Table 4) revealed that modification effects played a very marginal role in the overall interactions between media. Consequently, the variables pertaining to these effects were omitted from consideration in order to simplify remaining analyses.
2. As mentioned earlier, in-person communication and travel are likely to be strongly related activities. Indeed, the Pearson correlation matrix for replacement (interchangeability), generation, and elimination of in-person communication and travel yields eight significant ($\alpha = 0.05$) correlations out of a possible nine (see Table 3), with the three major diagonal correlations being especially large and significant. This suggests that a set of variables combining in-person communication and travel could be formed to reduce the dimensionality of our cluster analysis.
3. It is possible to focus only on DCN activities' relationships to offspring activities, i.e., their patterns of generation and elimination. However, it may be that activities are also meaningfully differentiated by their parent activities, or

TABLE 3
Pearson Correlation Matrix for Replacement, Generation, and Elimination of In-Person Communication and Transportation (N = 636)

	Transportation		
	Replacement	*Generation*	*Elimination*
In-person Communication			
Replacement	0.48**	0.12**	0.22**
Generation	0.19**	0.43**	0.10*
Elimination	0.14**	—	0.68**

* $p < 0.05$ (1-tailed); ** $p < 0.01$ (1-tailed); — no significant correlation.

lack thereof. It is, therefore, informative to include in some cluster analyses variables indicating whether a DCN activity was prompted by a communication in some medium.

4. Similarly, we also need to identify potentially interchangeable activities in different media, and therefore we should include in some analyses variables indicating whether a DCN activity had some other communication medium as a contemporaneous alternative (hence replacing the use of that alternative).

All of these considerations are useful. However, they are not so specific as to yield a single best set of dimensions for cluster analysis. Accordingly, separate cluster analyses were performed using two different dimension sets: 1) generation and elimination of future communications in our four medium categories (8 variables); and 2) prompting by, replacement of, generation of, and elimination of communications in electronic, object transfer, and *combined* in-person/travel medium categories (12 variables). Cluster analyses of additional dimension sets can be found in Balepur.

The processes of selecting an appropriate similarity measure and an appropriate clustering algorithm are somewhat intertwined, since certain algorithms are best implemented using certain similarity measures. In general, it would seem that the processes of selection of similarity measure, variable weighting method, and clustering algorithm are as much an art as a science. Although a complex, weighted, hierarchical clustering algorithm was also used to analyze the data for this study, its results did not differ substantially from those obtained using the standard SPSS implementation of the unweighted K-means "quick cluster" algorithm. The latter requires a much shorter running time, allowing a more thorough exploratory analysis, and therefore the unweighted K-means algorithm (with a simple matching similarity measure) was chosen as the preferred tool for this study.

Balepur

Results

Expected Effect Pattern Tabulation

Each DCN activity was coded in terms of its causal implications, i.e. whether it was expected to generate, eliminate, or modify some activity or activities in any medium (in-person communication, electronic communication, object delivery, or travel). Each

activity therefore was associated with a 12-variable pattern vector of binary variables ("bits") specifying its causal relationship to any offspring activities, where a "1" indicates that any outcome in that category was expected as a consequence of the current communication. Although there are $2^{12} = 4{,}096$ possible patterns, the 18 most frequent ones shown in Table 4 account for almost 80 percent of the cases.

This tabulation offers several interesting results. Turning first to the column totals to examine overall individual effects, we see that by far the most prevalent active effect (as opposed to a "no effect" effect) of a DCN activity was to generate another electronic activity: this occurred in 12 of the top 18 patterns and in 55 percent of cases overall. The next most common effect, generation of an in-person communication, occurs less than half as often, in six of the top 18 patterns and 22 percent of cases overall. It can be seen that generation effects are far more common than elimination effects (by a factor of eight, among the top 18 patterns), and that modification effects are negligible, as mentioned earlier. About twice as many communications involved generation of future in-person communication or travel (about 26 percent of the total, without double-counting those that generated both types of activities) as involved elimination of future in-person communication or travel (about 13 percent of the total).

Turning to the row totals to examine combinations of effects, additional results emerge. A large proportion (more than 30 percent) of the communications were simply stand-alone or neutral, causing neither generation, nor elimination, nor modification of any other communications. The second largest group (more than 23 percent) involved just the generation of electronic communication. For all offspring (effect) media, generation was the most common effect, with patterns involving generation-only effects accounting for 44 percent of the sample, and patterns including generation either alone or with other effects accounting for 65 percent of the total. By contrast, patterns involving only elimination comprise only 3.8 percent of the sample, and those involving elimination either alone or with other effects constitute 22 percent of the total. The most frequent patterns are relatively simple, exhibiting only one or two effects. Only five patterns among the top 18 exhibit three or more simultaneous effects, none of them individually accounting for more than 11 cases or 1.73 percent of the sample. However, this result may represent more a general inability on the part of respondents to imagine multiple or complex future effects than a genuine behavioral pattern.

TABLE 4
Distribution of Expected Effect Patterns

			Generate				*Eliminate*				*Modify*			
Rank	*Freq.*	*%*	*In-person*	*Electronic*	*Object*	*Travel*	*In-person*	*Electronic*	*Object*	*Travel*	*In-person*	*Electronic*	*Object*	*Travel*
1	191	30.03	0	0	0	0	0	0	0	0	0	0	0	0
2	149	23.43	0	1	0	0	0	0	0	0	0	0	0	0
3	26	4.09	1	1	0	0	0	0	0	0	0	0	0	0
4	15	2.36	1	0	0	0	0	0	0	0	0	0	0	0
5	15	2.36	0	1	1	0	0	0	0	0	0	0	0	0
6	15	2.36	0	1	0	1	0	0	0	0	0	0	0	0
7	14	2.20	1	0	0	1	0	0	0	0	0	0	0	0
8	11	1.73	1	1	0	1	0	0	0	0	0	0	0	0
9	11	1.73	0	0	1	0	0	0	0	0	0	0	0	0
10	10	1.57	1	1	1	0	0	0	0	0	0	0	0	0
11	9	1.42	0	1	0	0	1	0	0	1	0	0	0	0
12	7	1.10	1	1	1	1	0	0	0	0	0	0	0	0
13	7	1.10	0	1	0	0	0	0	1	0	0	0	0	0
14	6	0.94	0	0	0	0	1	0	0	1	0	0	0	0
15	6	0.94	0	0	0	0	0	1	0	0	0	0	0	0
16	5	0.79	0	1	0	0	0	1	0	0	0	1	0	0
17	5	0.79	0	1	0	0	0	1	0	0	0	0	0	0
18	5	0.79	0	1	0	0	0	0	0	0	0	1	0	0
Total (top 18)	507	79.72	83	264	43	47	15	16	7	15	0	10	0	0
%			16	52	8	9	3	3	1	3	0	2	0	0
Total Sample	636	100	140	351	81	81	66	69	57	68	13	26	6	15
%			22	55	13	13	10	11	9	11	2	4	1	2

While the fact that 18 out of 4,096 possible patterns capture 80 percent of the data indicates a remarkable degree of regularity in the data, some of the remaining 20 percent might be similar enough to the 18 patterns shown in the table, or to each other, to permit a regrouping. To explore this question, we use the technique of cluster analysis.

Expected Effect Cluster Analysis

By eliminating the four bits pertaining to modification from the pattern vectors used in the simple tabulations, we obtain eight-bit vectors that specify whether a given activity was expected to generate or eliminate any future in-person communication, electronic communication, object delivery, or travel. These were clustered into 29 groups, the top 15 accounting for more than 95 percent of all cases. Table 5 presents the centroids of these 29 clusters, that is, the average value on each variable for the members of the cluster. Since the input variables are binary, these averages represent the proportion of cases in the cluster possessing each characteristic. The largest cluster, accounting for nearly a third of all cases, is neutral, representing those DCN activities that neither generated nor eliminated communication in any mode. The next largest cluster accounts for about a quarter of all cases, and represents those DCN activities that generated an electronic communication. These two clusters, accounting for more than half of all cases, suggest that DCN activities were relatively independent of other communication media, and perhaps even self-generating, although it is possible that some of the electronic communications generated by DCN activity were phone calls.

The third largest cluster, accounting for 13 percent of all cases, represents activities that were expected to generate electronic communication, travel, and in-person communication. It is easy to imagine scenarios fitting this description: someone might receive an e-mail from a contact, generating a response by e-mail or by telephone, and a plan to travel to visit the contact for a face-to-face conversation. It is noteworthy that this cluster, the largest pertaining to travel, involves trip generation, not substitution. The next largest cluster pertaining to travel (the sixth largest overall)—representing activities that generate electronic communication, eliminate in-person communication, eliminate object delivery, and eliminate travel—accounts for only 3.14 percent of all cases. The nature of this cluster is evoked by one respondent's open-ended explanation: "... *E-mail communication*

TABLE 5
Eight-Bit Cluster Centroids (Expected Effect Patterns)[1]

				Generate				*Eliminate*			
Cluster	*# of Cases*	*% of Cases*	*Cumulative %*	*In-person*	*Electronic*	*Object*	*Travel*	*In-person*	*Electronic*	*Object*	*Travel*
1	198	31.13	31.13	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
2	162	25.47	56.60	0.00	1.00	0.00	0.00	0.02	0.00	0.00	0.00
3	82	12.89	69.50	0.82	0.83	0.11	0.67	0.00	0.05	0.00	0.00
4	30	4.72	74.21	0.77	0.20	0.00	0.00	0.00	0.50	0.00	0.00
5	27	4.25	78.46	0.44	1.00	1.00	0.00	0.00	0.00	0.07	0.00
6	20	3.14	81.60	0.00	0.95	0.10	0.00	0.80	0.00	0.55	1.00
7	16	2.52	84.12	0.00	1.00	0.00	0.06	0.00	1.00	0.19	0.00
8	13	2.04	86.16	0.00	0.00	1.00	0.00	0.00	0.15	0.00	0.00
9	10	1.57	87.74	0.00	1.00	0.20	0.00	0.10	0.00	1.00	0.00
10	10	1.57	89.31	0.00	0.00	0.00	0.00	0.60	0.30	0.00	1.00
11	9	1.42	90.72	0.00	1.00	0.11	0.00	0.78	1.00	0.56	1.00
12	8	1.26	91.98	1.00	1.00	0.00	0.00	1.00	0.25	0.00	0.25
13	7	1.10	93.08	0.57	0.00	1.00	0.57	0.00	0.00	0.00	0.00
14	7	1.10	94.18	1.00	0.14	0.00	0.71	1.00	0.14	0.00	1.00
15	6	0.94	95.13	0.17	0.83	1.00	0.00	0.00	1.00	0.83	0.50
16	4	0.63	95.75	1.00	1.00	1.00	0.50	1.00	0.00	0.00	0.25
17	4	0.63	96.38	0.25	0.00	0.00	0.00	0.00	0.25	1.00	0.00
18	4	0.63	97.01	0.00	0.00	0.00	0.00	1.00	1.00	0.50	0.50
19	3	0.47	97.48	1.00	1.00	0.67	0.00	1.00	0.00	1.00	1.00
20	2	0.31	97.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
21	2	0.31	98.11	1.00	1.00	1.00	0.50	0.00	0.00	1.00	1.00
22	2	0.31	98.43	0.00	0.50	0.00	1.00	0.00	0.00	1.00	0.00
23	2	0.31	98.74	1.00	1.00	0.00	1.00	0.50	1.00	1.00	1.00
24	2	0.31	99.06	0.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00
25	2	0.31	99.37	0.00	1.00	0.00	1.00	0.00	0.00	1.00	1.00
26	1	0.16	99.53	1.00	1.00	1.00	1.00	0.00	1.00	0.00	1.00
27	1	0.16	99.69	1.00	0.00	0.00	1.00	1.00	0.00	1.00	0.00
28	1	0.16	99.84	1.00	1.00	0.00	0.00	0.00	0.00	1.00	1.00
29	1	0.16	100.00	1.00	0.00	1.00	1.00	1.00	1.00	0.00	1.00
Top 15	605			122	331	67	65	50	58	36	51
Percent	95			20	55	11	11	8	10	6	8
Total	636			140	351	81	81	66	69	57	68
Percent	100			22	55	13	13	10	11	9	11

[1] Cells are shaded dark gray if their value is one or (in one case) 0.95, and light gray if their value is greater than or equal to 0.5 (meaning that at least 50 percent of the cases in the cluster expected this category of effect to occur).

eliminates the necessity for an in-person meeting and transfer of review document hardcopy."

Extended Cluster Analysis

The identification of parent and replacement media requires the inclusion of variables indicating whether a DCN activity was prompted by an activity in some medium, and whether a DCN activity had an alternative in some other medium. In the *Activity Survey*, respondents were not asked whether travel prompted DCN activities, on the assumption that it would be the activities at travel endpoints that would prompt other activities, not the travel itself. However, as noted earlier, direct substitution, generation, and elimination of in-person communication and travel were found to be significantly correlated. Accordingly, it seemed appropriate to consolidate the heavily redundant information contained in these two sets of variables, thereby reducing the dimensionality of the cluster analysis. We created a new set of three binary variables (for replacement, generation, and elimination) coded as "1" if a corresponding in-person or transportation variable was coded as "1". These were then substituted in the pattern vector for their corresponding in-person and transportation variables. In addition, three new "prompting" bits were added to the cluster analysis, representing prompting by in-person communication, electronic communication, and object delivery, and three new bits were added indicating whether respondents could have chosen to engage in in-person communication (or travel), electronic communication, or object delivery instead of DCN activity.

The adoption of this dimension set produces twelve-bit pattern vectors. We adopted a partition of the 634 available vectors into 44 clusters, with the largest 27 of these accounting for about 94 percent of all cases, as shown in Table 6.

The column totals of this table provide further evidence that DCN activities causally interact with other electronic communications more than with other activities, with the overall effect of generating additional electronic communications. Electronic communications prompted 50 percent of all DCN activities, and (as already seen in Tables 4 and 5) 55 percent of all DCN activities generated electronic communications. By contrast, only 39 percent of all DCN activities replaced other electronic communications (over half of which consisted of phone use and only 8 percent of which constituted other uses of the Internet), and only 11 percent of all DCN activities eliminated future electronic

TABLE 6
Twelve-Bit Cluster Centroids (Cause, Alternative, and Expected Effect Patterns)[1]

			Prompt			*Replace*			*Generate*			*Eliminate*		
# of Cases	*% of Cases*	*Cumulative %*	*In-person*	*Electronic*	*Object*	*In-person/ Travel*	*Electronic*	*Object*	*In-person/ Travel*	*Electronic*	*Object*	*In-person/ Travel*	*Electronic*	*Object*
165	25.94	25.94	0.00	0.53	0.01	0.00	0.00	0.00	0.00	0.29	0.02	0.01	0.01	0.01
66	10.38	36.32	0.30	0.00	0.06	0.00	1.00	0.02	0.23	0.42	0.02	0.00	0.00	0.02
57	8.96	45.28	0.00	1.00	0.05	0.02	1.00	0.00	0.12	0.70	0.00	0.02	0.00	0.00
45	7.08	52.36	0.04	0.00	0.18	0.00	0.00	0.11	0.18	1.00	0.07	0.00	0.02	0.02
19	2.99	55.35	0.11	0.89	0.05	0.05	0.00	0.05	1.00	1.00	0.47	0.37	0.05	0.00
19	2.99	58.33	0.00	1.00	0.00	0.53	0.32	0.05	0.84	0.05	0.00	0.11	0.05	0.00
17	2.67	61.01	0.29	0.24	0.06	0.76	1.00	0.18	1.00	1.00	0.59	0.00	0.00	0.00
16	2.52	63.52	0.06	1.00	0.19	0.06	0.94	0.00	0.44	0.88	0.00	0.00	1.00	0.13
16	2.52	66.04	0.00	1.00	0.00	0.81	0.19	0.69	0.00	1.00	0.44	0.00	0.00	0.19
15	2.36	68.40	0.13	0.00	0.00	0.87	0.00	0.00	0.00	0.20	0.07	0.40	0.13	0.00
14	2.20	70.60	0.00	1.00	0.00	0.21	0.29	0.00	0.00	1.00	0.00	1.00	0.21	0.57
14	2.20	72.80	1.00	1.00	0.07	0.57	0.50	0.07	0.93	0.93	0.00	0.00	0.14	0.00
14	2.20	75.00	0.71	1.00	0.43	0.07	0.00	0.00	0.00	0.36	0.07	0.00	0.00	0.00
13	2.04	77.04	0.46	0.00	0.00	0.00	0.08	0.00	0.00	0.23	0.00	0.08	0.62	0.08
13	2.04	79.09	0.23	0.00	0.00	1.00	0.00	0.38	0.46	1.00	0.00	0.08	0.08	0.08
12	1.89	80.97	0.00	0.67	0.00	0.17	0.00	1.00	0.08	0.17	0.08	0.08	0.00	0.08
12	1.89	82.86	0.25	0.17	0.08	1.00	1.00	0.25	0.00	0.08	0.00	0.17	0.25	0.08
12	1.89	84.75	0.83	0.00	0.00	0.00	0.75	0.08	0.25	0.75	0.00	0.83	0.58	0.08
10	1.57	86.32	0.80	0.00	0.10	0.30	0.00	0.20	1.00	0.10	0.40	0.10	0.00	0.00
8	1.26	87.58	0.00	1.00	0.00	0.13	1.00	0.50	0.63	0.13	0.88	0.00	0.25	0.00
8	1.26	88.84	0.25	1.00	0.00	0.00	0.88	0.00	0.38	1.00	1.00	0.00	0.00	0.00
7	1.10	89.94	0.00	0.00	0.43	0.86	0.00	1.00	0.29	0.00	0.29	0.00	0.00	0.00
6	0.94	90.88	0.17	1.00	0.17	0.00	0.83	0.00	1.00	1.00	0.83	0.83	0.33	0.83
6	0.94	91.82	0.17	1.00	0.17	0.00	1.00	1.00	0.00	1.00	0.17	0.17	0.00	0.00
5	0.79	92.61	0.60	0.00	0.00	0.80	0.80	0.80	0.20	1.00	0.00	1.00	0.20	0.60
5	0.79	93.40	0.00	1.00	0.00	1.00	0.80	1.00	1.00	1.00	0.40	0.40	0.00	0.00
5	0.79	94.18	0.60	0.00	0.00	1.00	0.80	0.00	1.00	0.00	0.00	0.60	0.00	0.20
4	0.63	94.81	0.75	1.00	0.00	0.25	0.25	0.75	1.00	1.00	0.50	0.50	0.00	1.00
30	4.72	99.53												
1	0.16	99.69	1.00	1.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
599			95.4	302	35.6	115	235	72.2	149	323	65.8	64	51.3	30.9
94			16	50	6	19	39	12	25	54	11	11	9	5
634			113	321	55	139	248	94	165	351	81	85	69	57
99.7			17.8	50.5	8.6	21.9	39.0	14.8	25.9	55.2	12.7	13.4	10.8	9.0

[1] Cells are shaded dark gray if their value is one, and light gray if their value is greater than or equal to 0.5.

communications. Hence, not only do the DCN effects reported here tend towards the production of electronic communications, but in fact these effects also probably tend to increase the relative quantity of Internet use.

It is also interesting to notice that a substantial number of DCN activities were prompted by in-person communications (18 percent of all cases, 16 percent of the cases in the top 33 clusters). However, this underestimates the extent of the general effect of travel on telecommunications, since only DCN activities are the focus of interest here. (The same, of course, can be said of the other prompts as well.) Obtaining a more accurate assessment of the influence of each form of communication on all the others would require an instrument such as the *Activity Diary* to be applied to communications of all types, not just DCN activities. A primitive precursor of such an instrument, namely the *Communications/Travel Log* mentioned earlier (trading off the greater depth of the *Activity Diary* for greater breadth of activities covered), was administered in this study; the results are reported in Mokhtarian and Meenakshisundaram.

A similar number of DCN activities contemporaneously replaced in-person communication/travel (22 percent of all cases, 19 percent of the cases in the top 33 clusters). This provides some evidence of the hypothesized ability of telecommunications (Internet use) to substitute for travel.

Turning to the rows of the table, the twelve-bit results diverge somewhat from those involving only effect patterns. For example, the largest cluster, accounting for 26 percent of all cases, was not purely neutral, but instead represented activities that were prompted by an electronic communication, with few other effects and replacing no alternative media. The second largest cluster (10 percent of all cases) represents activities replacing an alternative electronic medium. In fact, no purely neutral clusters appear in the twelve-bit analysis, indicating that members of such clusters in the earlier stages have been grouped differently here (due to their prompt and replace characteristics). The second- and third-largest clusters represent DCN activities replacing some alternative electronic medium, and many of the clusters represent prompting by an electronic communication or expected generation of electronic communication.

Substantial interaction with travel or in-person communication appears first in the fifth-largest cluster (3 percent of all cases), where either in-person communication or travel is generated by (electronically prompted) DCN activities that also

generate some kind of electronic communications. In the sixth, seventh, and twelfth clusters, we also see the pattern that replacement of in-person communication or travel by DCN is more than counteracted by downstream effects generating in-person communication or travel (without a compensating downstream elimination effect).

Conclusion

This study has presented and applied a methodology for qualitatively assessing communication patterns associated with Internet use. For the demonstration sample of 148 early adopters, the multiple empirical analyses present essentially similar pictures of the relationships between the 636 Internet activities studied (of which e-mail and Web browsing were a majority) and communications in other media. Almost a third of all Internet activities did not substitute for in-person communication, travel, physical object exchange, or electronic communication, nor was that third expected to generate or eliminate future activities in any of these media. About half of these "neutral" communications were prompted by some electronic communication and had no alternative, suggesting that many Internet activities were "self-generated" by the increased availability of electronic communications media. To the extent that Internet activities could have been pursued using alternative media, their alternatives also tended to involve electronic communication. This is consistent with the finding reported by NUA in 1995 that Internet use leads to decreased long-distance telephone use.

NUA, "Internet Displaces TV and Phone Use"

However, some Internet activities were also expected to generate future travel or in-person communication, some contemporaneously replaced travel or in-person communication, and a few were expected to eliminate future travel or in-person communication. As might be expected given the relative insubstitutability of electronic documents for some objects (even those containing information being communicated) and the relative dominance of the telephone over mail for interpersonal communication, Internet activities bore no strong relationship to object-mediated communication. These results are essentially robust with respect to the selection of clustering dimensions, number of clusters, and clustering algorithm.

Balepur

The findings of the empirical portion of this study suggest that very many Internet activities bore essentially no direct

causal relation to travel. However, they also reveal not insignificant amounts of replacement and generation of travel on the margin. While this study is not well suited for a comprehensive evaluation of the net effects of Internet use on travel, the explicit consideration of (self-reported) causal connections in these analyses offers added explanatory value. For example, it is interesting to note the presence of strong (reported) causal connections between Internet activities and other electronic communications, and the large number of cases in which Internet activities had no alternative medium. These patterns suggest a process of self-generation, whereby the emergence of new electronic media stimulates new activities using those media that would otherwise be impossible.

Of course, these patterns should be interpreted with caution, for at least two reasons. First, the variables analyzed here are of necessity only imprecise indicators of the causes and effects of interest. A given binary variable in any of the patterns analyzed is equal to one if the respondent envisions the stated cause or effect of the current Internet communication. The question wording gave no limitation on the time frame or number of causes and effects in question. Some Internet activities may be part of a very long chain of causes and effects, ultimately embracing several outcome and media types, while other communication chains may terminate very quickly. Even for chains of similar actual length, some respondents will be more capable of identifying past causes and imagining future effects than others, and hence the set of reported causes and effects could underestimate the scope of the actual ones. Finally, even if all past causes and future effects of the current communication were completely and accurately captured, we would not be able to say with confidence that, for example, travel generation effects outweighed elimination effects, since (as in the Claisse and Rowe study mentioned earlier) we have no information on the lengths of trips generated versus those eliminated. More trips could be generated than eliminated, but the change in total *distance* traveled by any given person could vary greatly, depending upon the relative total distance covered by the generated and eliminated trips. Thus, these results can only be taken as suggestive outlines of general patterns, and not as a precise accounting of one type of effect against another.

The second reason these specific results should be interpreted with caution is the unknown extent to which they can be extrapolated to the present situation. Technological

development and institutional support have substantially changed the Internet in the intervening years, especially with regard to bandwidth limitations, multimedia capability, and public key encryption. Improvements in online transactions security and the mainstreaming of e-commerce have, in particular, been shown in recent studies to impact travel, at least slightly. Furthermore, services such as e-mail and the World Wide Web are not only more accessible today than in 1994, they also have higher utility precisely because of that greater diffusion of access and hence adoption. While only 6.7 percent of the total U.S. population reported having accessed the Internet in the three months prior to being surveyed in 1995, by April 2002 that figure had reached 59.1 percent; thus the probability that a recent adopter can now use the Internet to communicate with existing contacts is much higher today than it was in 1994.

Lenz et al.

NUA 2003

Internet use may be close to saturation in the United States, given that the size of the online population declined very slightly after December 2000 (peaking at 59.8 percent of the total U.S. population).[1] By comparison, global markets for Internet use appear to offer ample room for growth (given that only 9.6 percent of the total world population is currently online). As adoption of Internet technology continues to diffuse throughout industrialized and industrializing societies, we might perhaps expect adopters' behavior to undergo transformations similar in some ways to those experienced by DCN participants in 1994. Obviously, the alternative transportation modes and communication media available to a typical resident of, for example, Lagos in 2005 would not have the same characteristics as those available to a typical Davis resident in 1994, and this fact suggests caution in generalizing to other countries and times using the findings presented here.

NUA 2003

[1]*The evidence for this assertion is provided by NUA, a company that monitors and compiles surveys from other sources, and that publishes along with its estimates the caveat that, "the art of estimating how many are online throughout the world is an inexact one at best"* (NUA, "Internet Use Climbing in Most Markets"). *Nonetheless, NUA's data are widely used and respected as one of the best available sources of information on the global online population* (Norris). NUA 2003

Yet the methodological technique of using a survey instrument to observe generative and substitutive relationships between activities of different media could be applied in any context in which a relatively new medium has recently entered individuals' choice sets. It is precisely at this early point in the adoption cycle, when respondents have not yet developed habitual responses that could mask or subdue the salience of substitution or generation effects, that such a methodology is especially appropriate. In other words, an American respondent in 2005 might not perceive a relationship of substitutability between, for example, travel and e-mail use, since the shift

from the former to the latter, as a habitual choice, would have occurred long before receiving the survey. Therefore, although the data in this study are somewhat historical in nature, they represent descriptions by respondents of shifts in medium usage habits *as they occurred.* In 1994 almost all respondents could recall a time in which the Internet was not available as an option, and therefore the effects of the Internet's emergence were likely more salient then than they would be today.

The main purpose of this study has, therefore, been to present a methodology for assessing communication patterns. The empirical application served primarily to illustrate the implementation of the methodology, and the kinds of useful insights it enables. Secondarily, however, the empirical findings offer a valuable benchmark against which to compare future results obtained using similar or improved instruments to collect new data. As part of such efforts, it would be desirable to broaden the scope of research to more fully capture the effects of forms of communication other than Internet activities.

The methodology proposed here is by no means suggested to be definitive, however. Since it involves self-assessments of general impacts (which, as mentioned earlier, can only be imprecise and qualitative), its application should be supplemented with more quantitative assessments of changes in communication patterns over time. Fruitful directions for future research may also include normative inquiry. As the research to date has focused on the behavioral impacts of well-defined, exogenously determined technologies, we cannot yet ascertain what kinds of telecommunications technologies would, in fact, act as better substitutes for travel, nor which social circumstances would facilitate their substitution. Furthermore, the consumer reaction to technologies that, in the limit, replicate travel-based face-to-face communication, is, as yet, unknown. Policy questions abound; for example, one might attempt to ascertain what travel and emissions savings could be achieved via universal access policies (potentially crucial if any other policies depend upon growth in the population of Internet users beyond natural market saturation levels). More generally, while engaging in the continuing study of the likely impacts of telecommunications on travel, one might also identify constraints (technology, accessibility) that could be amenable to policy intervention. In any case, researchers of the implications of Internet use for travel are still in effect tracking a "moving target."

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