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Effective combinations of information content and channels for the post-disaster reconstruction of rural housing: A case study of the 2015 Gorkha Nepal Earthquake

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ABSTRACT

For the recovery of rural communities in developing countries, providing appropriate information in an appropriate manner is critical. This study aimed to statistically examine how the content and channels influence the activities of households in developing country rural communities to recover from disasters. As a key recovery activity, we focused on the reconstruction of houses damaged by the 2015 Gorkha Nepal Earthquake. We employed survival analysis to test the effects of various combinations of information content and channels on: repair starting times and rebuilding completion times. Three types of information content were considered: (1) "scientific information" with respect to aftershocks, (2) "technical information" with respect to materials and methods for reconstruction, and (3) "financial aid information" with respect to financial support in the form of subsidies and loans. Two channel types were considered: (1) "linking networks," in which, channels are provided by government and/or non-governmental organizations, and (2) "bonding networks," in which channels are between neighbors and/or family members/relatives. We found that households obtaining scientific information through linking networks had earlier repair starting times and rebuilding completion times, while households obtaining technical information through bonding networks had earlier starting times. It was also found that households obtaining financial aid information started repairs later than other households, and if financial aid information was obtained through linking networks, rebuilding completion was significantly delayed. Our findings suggest that providing information in an effective manner and designing appropriate institutions can accelerate the recovery process.

1. Introduction

In the aftermath of a disaster, affected local communities are expected to demonstrate resilience by functioning effectively and adapting properly [1–4]. Vulnerable communities in developing countries must take the further step of conducting many of their own recovery activities, as only limited material aid can be expected from outside of the community. Factors that can help ensure that autonomous recovery takes place include, for example, (1) social capital in the form of social networks and resources that can be accessed through network ties, (2) information and communication channels [2] in the form of trusted sources of information, and (3) community resources [3] corresponding to the degree of networking of community leaders with resources outside of the community. In other words, the effectiveness of the recovery process is determined by the robustness of the social networks that involve community members and the resources and information that can be mobilized through ties within these networks; this is a formulation that has become a commonplace within the research community [5–13].

Studies on risk communication have found that the meaning of information can change during the transmission process. This can occur, for example, through social amplification, in which the public perception of risk is heightened during the transmission of risk information, generating unfavorable social consequences [14]. Other studies in the field of science communication [15] have found that information is understood not when it is delivered but only after it is located within the context or situation of the recipients. Such results suggest that information providers should deliver information in such a manner that it can be adjusted by recipients to their context or situation.

Considering the above discussion, the effect of information on a recipient's perception and behavior can vary depending on not only the content but also the channels through which it is transmitted. Thus, any

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discussion of promoting autonomous recovery actions to enable effective recovery activity should shed light on the content and source of the information.

To understand the effects of information content and channel mechanisms on enabling recovery activity by affected populations, it is particularly meaningful to look at rural communities in developing countries, as such communities are less likely to depend on outside resources and therefore may not be familiar with outside information content that could otherwise successfully enhance recovery activities. In such cases, the effect of provided information on perception or behavior can vary significantly depending on its content. In addition, outside stakeholders from cities or developed countries with social contexts that are more heterogeneous than those of the communities they attempt to aid can provide information without fully understanding the local context or background. Thus, the effect of information on the perception or behavior of a recipient can differ significantly depending on the channels used to provide the information. However, the ways in which the combinations of information content and channel promote the recovery actions in rural communities have not been quantitatively examined.

The goal of this study was to identify the information content and channel combinations that most effectively promote recovery activity by disaster-affected rural residents in a developing country. To better understand this, we conducted interview-based surveys of household members in the rural communities affected by the 2015 Gorkha Nepal Earthquake [16,17]. To determine the rate of recovery, we had to determine how to objectively define the recovery progress; however, simply asking respondents how much they had recovered would elicit highly subjective responses. To avoid this ambiguity, we focused on actions related to housing reconstruction, i.e., the repair and rebuilding of houses. By asking respondents when they undertook the actions of starting repair and completing rebuilding, we were able to obtain ready answers that allowed us to quantify the recovery progress. Using these data, we were able to statistically analyze how the information content regarding reconstruction and the channels through which it was relayed affected the key metrics of repair starting time and house rebuilding completion time.

The remainder of this paper is organized as follows: Section 2 presents a literature review; Section 3 shows our analytical framework; Section 4 presents the study area and data collection method; Section 5 presents the variables and models used for our analysis; Section 6 shows the estimation results; Section 7 discusses the statistically analyzed results, and; Section 8 concludes the study and describes future work.

2. Literature review

Previous disaster research has quantitively analyzed the effects of information content and channel on perception and actions. Some of these studies have focused on the situation prior to a disaster by analyzing how pre-existing information channels influence risk perception or awareness and acceptance of prevention action [18,19]. Other studies have focused on post-disaster situations by concentrating almost exclusively on the effects of information modalities on evacuation behavior immediately following a disaster. For example, DeYoung et al. [20] revealed that the type of channel used to gather information regarding hurricane evacuation differed by ethnic group and possibly affected the length of time needed to make decisions regarding protective actions. Sadri et al. [21] explored how an individual's characteristics and those of the people with whom they interact closely during a hurricane impact joint evacuation decisions. Sadri et al. [22] examined how individual evacuation decision-making was affected by both information channel type, e.g., radio and television, social media, or internet, and the characteristics of the social ties among individuals who closely interact during hurricane events.

Despite the increasing number of studies focusing on the effects of information on perception and actions before or immediately after disasters, the recovery process has not been focused on. Recently, due to the increasing availability of online data (e.g., Twitter data), not only the contents of information and support discussed by people before and immediately after disasters [23–28] but also those long after disasters [29,30] have been studied intensively. However, only a few studies have focused on the information effects on recovery activities following disasters. To the best of our knowledge, only Akbar and Aldrich [31] and Sadri et al. [32] have quantitatively investigated how social networks or the support provided thereon influence the long-term perception and recovery activities of households following disasters. Akbar and Aldrich [31] examined the role of post-disaster social support received from family, friends, and neighbors after a disaster in enhancing life recovery through self-assessments of the recovery of health, livelihood, and quality of life. In an approach similar to that applied in this study, Sadri et al. [32] discussed recovery from damage to household physical components such as homes and vehicles. More specifically, they tested the effects of various factors on the time required by a household to completely recover from damage. Such factors include the personal network structures of people with whom families interact closely during tornado evacuations and/or recovery and the usefulness and promptness of assistance from friends, neighbors, government, and others throughout the recovery process. However, as neither study distinguished the content of the support received by the households, the effectiveness of the information content transmitted through specific social networks could not be effectively ascertained.

Thus, although the information type and channels used to provide support to affected households can affect how well they recover, the results of these studies do not clarify the type of information that should be provided and the source of this information.

In addition, the permanent housing reconstruction is a key metric to represent the recovery of rural communities in developing countries. This is because, in developing countries, housing is usually the most valuable asset for the residents [33], but the impact of disasters on the built environment is much more severe than that in developed countries, estimated to be more than 20 times in magnitude [34]. In the 2015 Gorkha Nepal Earthquake, over half of a million houses were severely damaged or destroyed, primarily in rural areas [35]. Our survey also demonstrated that more than half of the households in the study area felt that they had experienced some problems with their houses during the recovery process [36]. Previous studies focusing on housing reconstruction in developing countries qualitatively discussed the role of guidelines [33], participatory planning [37–39], and resource management [40–42], but none of them quantitatively examined the effect of the provided information on rural housing reconstruction.

3. Framework of analysis

To address the research gap identified in the preceding section, we quantitatively examined what information content and types of information channel can most effectively improve the autonomous recovery of disaster-affected households.

Specifically, we applied a survival analysis approach to determine the effect of (1) content and (2) information channel on (a) house repair starting date and (b) rebuilding completion time. Survival analysis [43–45] is the study of the length of time until the occurrence of a specific event; such times will be non-negative and, in some cases, extremely long. Through a regression model, how the length of time is influenced by explanatory variables is investigated. For example, Mojtahedi et al. [46] focused on the time until the transportation infrastructure was completely recovered from the failure caused by disaster. They tested the effect of the explanatory variables such as “types of disaster” and “geographical regions” in which the transportation infrastructure was located on the recovery time.

Our study focused on two separate events: “start of repair” and “completion of repair or rebuilding” (which is referred to as "completion of rebuilding" hereafter). Such events were deemed to be appropriate for the purposes of our survey because they are easy to objectively quantify and nearly all disaster-affected households are expected to experience both. In summary, the study analyzed how the lengths of time until the occurrence of "start of repair" and "completion of rebuilding," respectively, were influenced by the content of information supplied to households and the channel of information used to supply it.

The following three information content types were considered:

(1) "scientific information," e.g., information regarding earthquake risk such as aftershocks;
(2) "technical information," e.g., information regarding the materials and techniques used for repair and rebuilding;
(3) "financial aid information," e.g., information regarding financial assistance such as subsidies and loans used for repair and rebuilding.

Obtaining information from another person requires that there be a connection with him or her. An individual's connections are sometimes regarded as their social capital [47,48]. In general, connections can be classified into three varieties: "linking," "bonding," and "bridging" ties [8,9,48]. Roughly speaking, linking describes vertical connections between citizens and the explicit, formal, or institutionalized power or authority gradients in a society. By contrast, bonding and bridging ties are horizontal relationships between those in similar social positions. Bonding ties are connections between individuals who are emotionally close such as friends or family and correspond to tight bonds to a particular community. Bridging ties are present between loosely connected individuals and can span different communities.

Using this classification scheme, we categorized the channels of information used in the communities we studied. Our interview survey demonstrated that only around 1% of the households obtained information from friends outside of their communities, and thus, the study focused only on "linking" and "bonding" ties, which are referred to hereafter as "linking" and "bonding" networks, respectively. We defined these respective network types as being utilized if a household obtained information from the following individuals or organizations:

(1) Linking networks were used by households obtaining information directly from the government and/or non-governmental organizations (NGOs).
(2) Bonding networks were used by households obtaining information directly from neighbors and/or family members/relatives.

Through the application of survival analysis, the study sought to investigate how obtaining each of the three information content types ("scientific," "technical," and "financial aid") through each of the two channels ("linking" and "bonding" networks) affected the times at which repairs commenced and rebuilding finished.

4. Outline of survey

4.1. Study area

The study area focused on Balthali in the Kavrepalanchok District of the Bagmati Zone of central Nepal, which was affected by the 2015 Gorkha Nepal Earthquake. The rural communities targeted in this area are located approximately 100 km from the earthquake epicenter in Gorkha. The study area included approximately 850 households and 2,500 residents at the time of the survey [49]. Balthali is located in a mountainous area in which the main industries are paddy field agriculture and stock-farming of goats and buffalo. Owing to the mountainous terrain and poor transportation infrastructure (Fig. 1), rainy season precipitation can significantly worsen road conditions and can cut local communities off from outside contact.

Fig. 1. Bridge on the single route connecting target site with urban area (photo by authors).

Based on the severity of damage and in order of priority for rescue and relief operations, the government of Nepal categorized the earthquake-affected districts as: (1) severely hit, (2) crisis hit, (3) hit with heavy losses, (4) hit, and (5) slightly affected [50,51]. Kavrepalanchok was categorized as crisis hit. Nearly all houses in Balthali are constructed from bricks, and many were completely or partially damaged by the earthquake. In some areas, approximately 80% of houses were reported to be completely destroyed [49]. In the immediate aftermath of the earthquake, many occupants had lost their houses and were forced to reside outside, in tents, or in temporary shelters (Fig. 2). The recovery process varied considerably among affected households. Nearly three years after the earthquake, some households remain in temporary shelters; others reside in damaged houses (Fig. 3). Some have repaired or rebuilt their houses (Fig. 4).

Following the earthquake, the government and NGOs provided residents with aid. Caritas, a Christian NGO [52], provided affected households with farm animals and crop seeds and installed solar panels to generate electricity. The government provided subsidies for the repair and rebuilding of houses according to damage level as well as technical guidance for the reconstruction of houses. Approximately 550 households out of 850 in Balthali were eligible for the government subsidies [49]. Such NGO and government-provided aid was helpful in the process of rebuilding many houses (Figs. 5 and 6) undertaken by

Fig. 2. Temporary shelters (photo by authors).

Fig. 3. Damaged house (photo by authors).

Fig. 4. Rebuilt house (photo by authors).

Fig. 5. Construction of foundation (photo by authors).

households with the help of community members. As described above, the government has required affected households to actively get involved in housing reconstruction (i.e., owner-driven reconstruction) [35,53]. In other words, households in the study area took the initiative for the reconstruction actions to recover from severe damage. In addition, the study area had limited road access to the outside even before the earthquake, and thus, unfamiliar information for reconstruction may have been provided from unfamiliar stakeholders after the earthquake. This implies that the effect of provided information on their actions could vary significantly depending on its content and channel. Therefore, through this case study, we could investigate how the content and channel of information obtained by households in vulnerable rural communities, who were able to take the initiative of their reconstruction, contributed to their long-term recovery.

Fig. 6. Construction of frame (photo by authors).

4.2. Survey method

The authors conducted a door-to-door survey targeting households in Balthali between 30 November and 4 December 2017 and between 9 and 10 December 2017. Households were selected randomly and all contacted participants agreed to respond to the interview survey. The total sample size was $n = 124$, and it accounted for approximately 15% of the overall population. The survey assistants, who were native speakers of Nepalese, asked the following questions in Nepalese:

(1) **Household characteristics and damage to houses:** Number of family members, migrant workers, and school-attending children; family structure; occupation and age of head of household. Impression of damage to house: either "some damage" or "very severe damage."
(2) **Channels of information accessed to obtain information on repair and rebuilding of houses:** Persons or organizations through which households obtained scientific, technical, and/or financial aid information regarding repair and rebuilding.
(3) **Repair start date of and rebuilding completion date:** (i) Date when household started repairs and (ii) date when household completed repair or rebuilding.

5. Survival analysis

This section explains the conditions of the survival analysis used to determine when events occurred and the explanatory variables and models used for survival analysis.

5.1. Occurrence time of events

The histograms and cumulative distribution of time of occurrence of the first event—start of repair of house—are shown in Fig. 7, while the

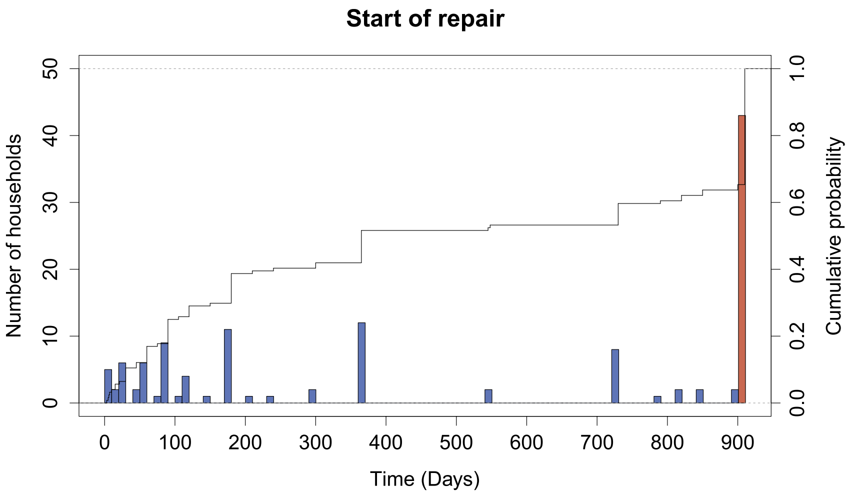

Fig. 7. Histogram and cumulative distribution of starting time of repair in terms of number of days (d) that have passed since the earthquake occurrence (the red histogram bar at 910 d represents households that had not started repairs by the survey date). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

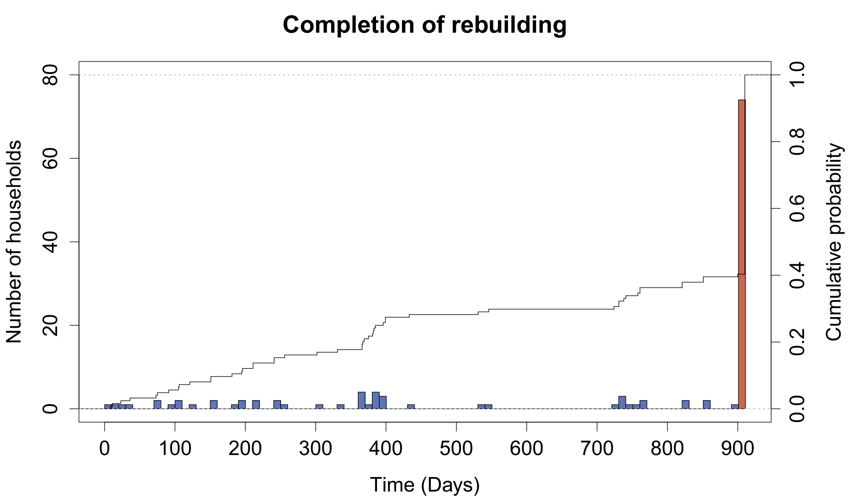

Fig. 8. Histogram and cumulative distribution of completion time of rebuilding in terms of number of days (d) that have passed since the earthquake occurrence (the red histogram bar at 910 d represents households that had not completed rebuilding by the survey date). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 1
Variables describing content and channels of information $\boldsymbol{X}_i$.

Variable name	Definition	Mean
SL	1: Scientific information is obtained through linking networks. 0: Otherwise.	0.524
SB	1: Scientific information is obtained through bonding networks. 0: Otherwise.	0.806
TL	1: Technical information is obtained through linking networks. 0: Otherwise.	0.855
TB	1: Technical information is obtained through bonding networks. 0: Otherwise.	0.419
FL	1: Financial aid information is obtained through linking networks. 0: Otherwise.	0.685
FB	1: Financial aid information is obtained through bonding networks. 0: Otherwise.	0.677

corresponding figures for the second event—completion of house rebuilding—are shown in Fig. 8. The horizontal axis of each figure represents time in units of days (d) from the occurrence of the earthquake, while the left and right vertical axes indicate (1) the number of households that experienced the corresponding event and (2) the cumulative probability that a household would have experienced the event by that period, respectively. The histograms are drawn over 10 d intervals. The survey was conducted 910 d after the earthquake. The red histogram bars at 910 d in each figure represent the number of households that had not experienced the corresponding events by the time of the survey; these households were therefore assumed to experience the respective events at some point after 910 d.

As seen from Fig. 7, approximately 40% of the sampled households began repairs within a year of the earthquake, while approximately 70% began repairs by the date on which the survey was conducted. Meanwhile, as shown in Fig. 8 approximately 15% of the households finished rebuilding within a year of the earthquake, while approximately 40% had finished rebuilding by the survey date.

5.2. Explanatory variables

5.2.1. Variables used to represent the combinations of information content and channels of information $\boldsymbol{X}_i$

The study looked at three information content types (“scientific,”

Table 2
Control variables W_i.

Variable name	Definition	Min	Mean	Max	SD
Migrant	Number of migrants in household.	0	0.744	8	1.195
Farmer	Farmer dummy. 1: Household head is a farmer. 0: Otherwise.	0	0.839	1	0.370
Damage	Damage dummy. 1: Subjective damage to house is "very severe." 0: Otherwise.	0	0.677	1	0.469
Age	Age of the head of household. 0: the age of the head is less than 30.1: 30s. 2: 40s. 3: 50s. 4: 60s. 5: 70s. 6: 80s or above.	0	2.750	6	1.507
Children	Number of school-attending children.	0	1.073	4	1.053

"technical," and "financial aid") and two social network types ("linking" and "bonding"). Accordingly, six dummy variables were used to represent all potential combinations of information content and network. The definitions of these dummy variables and their respective descriptive statistics are listed in Table 1. The variables corresponding to each household i are denoted by the vector X_i.

5.2.2. Control variables W_i

In addition to these variables, the repair start and rebuilding completion times should be affected by the household's attributes and the damage to the house, which were therefore set as control variables and are listed and defined in Table 2. The control variables for household i are denoted by the vector W_i.

5.3. Models

We start by considering the first event, "start of repair." The length

Table 3
Estimated parameters for each event from Cox and Weibull PH models.

	Start of repair		Completion of rebuilding	
	Cox PH	Weibull PH	Cox PH	Weibull PH
Migrant	−0.163 (0.148)	−0.156 (0.150)	−0.244 (0.157)	−0.249 (0.158)
Farmer	−0.680* (0.421)	−0.682 (0.423)	−0.653* (0.391)	−0.628 (0.390)
Damage	−0.441 (0.307)	−0.435 (0.307)	−0.349 (0.296)	−0.378 (0.296)
Age	0.055 (0.113)	0.074 (0.112)	0.021 (0.104)	0.025 (0.104)
Children	0.194 (0.148)	0.215 (0.148)	0.061 (0.146)	0.063 (0.146)
SL	1.446*** (0.414)	1.466*** (0.414)	1.585*** (0.382)	1.591*** (0.382)
SB	0.172 (0.444)	0.079 (0.439)	0.193 (0.419)	0.203 (0.417)
TL	0.263 (0.528)	0.320 (0.533)	0.402 (0.492)	0.385 (0.493)
TB	0.814* (0.436)	0.887** (0.439)	0.434 (0.413)	0.434 (0.414)
FL	−1.020** (0.410)	−1.093*** (0.413)	−1.396*** (0.417)	−1.384*** (0.415)
FB	−1.030** (0.455)	−1.102** (0.460)	−0.775* (0.456)	−0.779* (0.456)
log(shape parameter)		−0.123 (0.120)		0.037 (0.128)
log(scale parameter)		6.689*** (0.701)		6.817*** (0.610)
Log likelihood	−202.949	−388.103	−213.900	−407.188
LR Test (df=11)	29.584***	31.375***	31.144***	31.361***

Note: Standard errors in parentheses. * $p<0.1$; ** $p<0.05$; *** $p<0.01$. Sample size $n = 124$.

of time that a household required to initiate repairs following the earthquake is denoted by time t (d) and follows a probability density function given by $f(t)$, which results in a cumulative distribution function $F(t)\,(=\int_0^t f(u)du)$. The survival function, $S(t)$, represents the probability that the time of occurrence of an event exceeds time t and is defined by $S(t) = 1 - F(t)$. By contrast, the hazard function $h(t)$ (often called the "hazard rate") describes the instantaneous occurrence rate conditional on non-occurrence of an event until time t and is given by $h(t) = f(t)/S(t)$. In this model, we let $h(t;\ \boldsymbol{X}_i, \boldsymbol{W}_i)$ denote the hazard function for household i, which has dummy and control variables $\boldsymbol{X}_i$ and $\boldsymbol{W}_i$, respectively. We apply a proportional hazard model to describe a hazard function $h(\cdot)$ dependent on $\boldsymbol{X}_i$ and $\boldsymbol{W}_i$ as follows:

$$h(t;\ \boldsymbol{X}_i, \boldsymbol{W}_i) = h_0(t)\exp(\boldsymbol{\beta}_1\boldsymbol{X}_i + \boldsymbol{\beta}_2\boldsymbol{W}_i), \tag{1}$$

where $h_0(t)$ is the baseline hazard, which is a function of t alone and denotes the hazard function of household i obtained by setting $\boldsymbol{X}_i = \boldsymbol{0}$ and $\boldsymbol{W}_i = \boldsymbol{0}$. The unknown parameter vectors $\boldsymbol{\beta}_1$ and $\boldsymbol{\beta}_2$ determine the level of hazard rate. If a parameter is positive with a relatively high absolute value, the effect of its corresponding explanatory variable on the hazard rate will be enhanced, indicating that the event is likely to occur earlier.

To assess the robustness of the estimation results, semiparametric and parametric models were applied. The former, "Cox proportional hazard model," does not require complete distributional specification of the baseline hazard, $h_0(t)$, and is denoted as "Cox PH model" hereafter. Parametric models, by contrast, specify the distribution of $h_0(t)$. We applied the Weibull PH model [46,54,55], which assumes $h_0(t) = (a/b)(t/b)^{a-1}$, where a (>0) is a shape parameter and b (>0) is a scale parameter. The validation of the above models elucidates the effects of the combination of information content and network (i.e., $\boldsymbol{X}_i$) on the hazard function $h(\cdot)$ regarding the "start of repair" event.

The "completion of rebuilding" event was analyzed in the same manner to determine how its occurrence was affected by the explanatory vectors $\boldsymbol{X}_i$ and $\boldsymbol{W}_i$.

As mentioned earlier, the survey was conducted at $t = 910$ d, at which point some households had not started repairs while others had not completed rebuilding. These households were assumed to be subject to right censoring [43] and the parameters were estimated using the maximum likelihood method taking into account the censoring.

6. Results

Table 3 lists the estimated results for the above models. The columns "Start of repair" and "Completion of rebuilding" list the estimated results for "start of repair" and "completion of rebuilding," respectively. It is seen that the results produced by the Cox and Weibull PH models are nearly identical. An assessment of the Schoenfeld residuals of the Cox PH model results confirmed that the proportional hazard assumptions for all variables were significant at the 5% level.

We next look at the estimation results for the respective events, focusing on variables that are significant at the 10% level in at least one of the two models (these variables are shaded in Table 3).

6.1. Start of the repair

We first examine the estimation results of the event "start of repair."

The estimated coefficients of "Farmer," "FL" (i.e., financial aid information obtained through linking networks), and "FB" (i.e., financial aid information obtained through bonding networks) all have negative values, i.e., households with farming as the main income source commenced rebuilding later than other households while households that obtained information with respect to financial assistance such as subsidies or loans commenced repairs later than households that did not.

By contrast, the estimated coefficients for "SL" (i.e., scientific information obtained through linking networks) and "TB" (i.e., technical information obtained through bonding networks) have positive values; in other words, households that obtained information on aftershocks through linking networks or information with respect to repair and rebuilding techniques through bonding networks commenced repairs earlier than households that did not.

6.2. Completion of rebuilding

We next turn to the estimation results for the event "completion of rebuilding."

The estimated coefficients of "Farmer" have negative values, indicating that households with farming as the main income source commenced rebuilding later than other households. The coefficients of "FL" (i.e., financial aid information obtained through linking networks) and "FB" (i.e., financial aid information obtained through bonding networks) are also negative, indicating that households gaining information on financial assistance via, e.g., subsidies and loans completed rebuilding later than households that did not. However, in contrast to the results for "start of repair," the absolute values of the coefficients of "FL" and "FB" differ significantly, with the former much larger than the latter. For instance, a change of "FB" under the Cox PH model from 0 to 1 decreases the hazard ratio by 54% ($\fallingdotseq |\exp(-0.775)) - 1| \times 100$) over the baseline hazard, while a change of "FL" under the same model over the same range decreases the hazard ratio by 75% ($\fallingdotseq |\exp(-1.396) - 1| \times 100$) over the baseline hazard. This result indicates that households receiving financial aid information through linking networks experienced a much longer delay in the rebuilding process.

Finally, the estimated coefficient of "SL" (i.e., scientific information obtained through linking networks) has a positive value, indicating that households that obtained information on aftershocks through linking networks completed rebuilding earlier than those that did not.

7. Discussion

The information content used and channels employed following a disaster are generally assumed to influence the long-term recovery activities undertaken by affected populations. In particular, unfamiliar information content is often provided to rural communities in developing countries by unfamiliar stakeholders, which means that the effects of provided information can differ significantly by content and channel. We focused on a benchmark recovery activity—reconstruction of houses—by quantitatively examining the effects of information content and channel on the timing of this action. The results of our analysis for repair start time and rebuilding completion time are summarized in Tables 4 and 5, respectively. We found that specific combinations of information content and channel had significant effects on the outcomes with respect to these variables. It is possible that confounding factors or household characteristics created correlations between information acquisition and the timing of taking recovery action. To isolate the effect of information acquisition itself on when recovery actions were taken, we attempted to remove the effects of potential confounding factors by controlling the household characteristics potentially relating to household income, educational level, family labor, and damage to the house (Table 2).

In the following, the results by information content type are discussed to discern the reasons for the observed results and to explore potentially better ways to provide information and aid.

7.1. Scientific information

From the standpoint of information accuracy, it is generally agreed that "scientific information" with respect to future earthquake risk should be delivered directly by authorized distributers of information, namely, governments and NGOs. In our study area, one interviewee

Table 4
Effect of content and channel combination on repair start time ("-": not significant).

	Scientific information	Technical information	Financial aid information
Linking networks (i.e., the government and/or NGOs)	Accelerate	–	Decelerate
Bonding networks (i.e., neighbors and/or family members/relatives)	–	Accelerate	Decelerate

Table 5
Effect of content and channel combination on rebuilding completion time ("-": not significant).

	Scientific information	Technical information	Financial aid information
Linking networks (i.e., the government and/or NGOs)	Accelerate	–	Significantly decelerate
Bonding networks (i.e., neighbors and/or family members/relatives)	–	–	Decelerate

who obtained information regarding aftershocks from their neighbors reported that "I heard a rumor that large aftershocks would occur, so although I already had come back to my houses from the temporary shelters, I returned to the shelters for the safety again." This interviewee ultimately remained in the shelters for nearly half a year, even after the aftershocks had faded away. Thus, the rumors spread by the neighbors might have induced an individual to overstay in a shelter. Kasperson et al. [14] noted that risk events interact with psychological, social, and cultural processes in ways that can amplify public perception of risk and related risk behavior. This phenomenon is referred to as social amplification of risk and can occur during the transfer of information regarding risk. To avoid social amplification of risk, scientifically accurate information should be transferred directly from the government and/or NGOs.

Our results demonstrated that households that obtained scientific information through linking networks (i.e., from the government and NGOs) commenced repair and completed rebuilding earlier than other households. This confirms the generally accepted notion that adoption of recovery actions can be sped up by transmitting scientific information directly from governments and NGOs.

7.2. Technical information

Turning to "technical information" regarding materials and methods for the repair and rebuilding of houses, we note that such information, which covers methods and tools for reconstructing highly earthquake-resistant houses, also requires accurate transmission. In the study area, the government and NGOs provided people with technical guidance for reconstruction of their houses. However, our results demonstrated that households that obtained technical information through "bonding networks" (i.e., community members such as neighbors and family members) commenced house repairs earlier.

This result was likely driven by the particular repair techniques applied within the study area. As shown in Figs. 5 and 6, reconstruction was carried out using local materials and methods—for example, locally sourced bricks and manageable methods for building with them. The effective use of such local materials and methods would require local knowledge, which would understandably be exchanged among community members.

Previous studies have also emphasized the effectiveness of utilizing indigenous materials and techniques to construct temporary houses [56,57]. Our results validate the findings of these studies and clarify that in situations in which local materials and reconstruction techniques are adopted, as in the domain of our study, the technical information provided through bonding networks effectively promotes autonomous recovery actions.

7.3. Financial aid information

Finally, we discuss the effects of "financial aid information" relating to financial assistance such as subsidies and loans for reconstruction. Although the provision of financial aid information was expected to promote recovery, our results indicate that households that were provided with such information through either bonding (neighbors and/or family members/relatives) or linking (the government and/or NGOs) networks did not start repairs earlier.

In this case, financial assistance information provided by the government and NGOs was essentially related to the availability of a government subsidy, which was disbursed to recipients following administrative procedures. Unfamiliarity with these procedures might partially explain the delay of onset of repair. A large proportion of the households within the study area were farmer families, and the region had limited road access to the outside even before the earthquake (Fig. 1). These conditions suggest a more independent—or self-sustaining—mode of life, corresponding to a reduced dependency on and interrelationship with monetary markets and the government and, consequently, less familiarity with and inability to navigate the administrative procedures. Another factor that could have contributed to delay in the start of repair is delays in the provision of the government subsidy [35].

The content of information relating to financial assistance obtained from neighbors and relatives centered primarily on the provision of personal loans and the government subsidy. The personal loans were generally obtained following a period of negotiation; however, such negotiations may have been hindered by difficulties in accessing the outside (Fig. 1), which made communication with outside family members and relatives difficult.

Overall, administrative procedures and negotiations with others to obtain grants and loans, respectively, resulted in increased time spent in acquiring funds to trigger repairs. The fact that households that did not receive outside financial information did not have to undergo either application or negotiation potentially explains the seemingly paradoxical result that not receiving outside financial advice correlated positively with earlier commencement of recovery activities.

Households that obtained financial aid information through bonding networks were also delayed in terms of rebuilding completion. This effect was potentially also triggered by the need to negotiate with neighbors and family members to obtain financial support, and the efforts to negotiate were likely hampered by geographical conditions.

Although the distribution of financial aid information by the government and NGOs would appear to be an appropriate and useful action, our results suggest that provision of such information via linking networks delayed the completion of rebuilding substantially. This result possibly reflects the complicated procedures that needed to be completed to receive the government subsidy following the commencement of rebuilding. Within the study area, the subsidy was disbursed incrementally depending on progress in rebuilding. In other words, it was provided only after each stage of reconstruction—namely, (i) laying of a foundation up to lintel/wall, and (ii) completed construction of a toilet, bio-gas plant, or solar power cells—was completed in a manner satisfactory to the specific standards of each stage as determined by the government [35,53]. Some households in the study area reported that "the official financial aid was helpful," suggesting that the subsidy did contribute to the reconstruction. Despite this, reported problems with the subsidy included delays in the payment procedure and lack of clear information on the official building procedures, payment process, and expected use of the subsidy during each stage [35]. As a result, the subsidy was not disbursed in some cases in which the building requirement was not satisfied and in other cases in which the subsidy was used in an unintended manner. Some interviewees in the study area complained that "what the government says regarding the reconstruction is inconsistent" while others noted that "I used the received money for daily necessities and food." Such problems were likely induced by the complicated nature of the subsidy payment procedure and potentially aggravated by the lengthy official inspections required for each reconstruction stage. Overall, our findings suggest that a number of problems with the official procedure applied increased the construction period and delayed the completion of rebuilding.

Although the establishment of a specific standard at each stage would be expected to encourage the reconstruction of high-quality houses, our results indicate that such administrative procedures may act as a bottleneck to the early completion of the rebuilding of better houses. Thus, such procedures should be simplified and adjusted to local contexts to render aid more effective. However, it is necessary to consider what trade-offs must be made between early reconstruction and reconstructed house quality. One interviewee who had finished reconstruction early noted that "the government told me that my rebuilt house does not satisfy the standard." Rules and procedures should be carefully designed to better assist the affected populations who actually receive and use financial aid.

8. Conclusion

The goal of this study was to quantitatively determine the information content and channels that more effectively promote recovery activities undertaken by disaster-affected rural households in developing countries. To this end, we applied the tools of survival analysis to test the effects of information content and channel on the repair start time and the rebuilding completion time in rural communities affected by the 2015 Gorkha Nepal Earthquake.

Our results demonstrated that certain information content and channel combinations had significant effects on the timing of these actions. Specifically, households that obtained scientific information (i.e., information regarding earthquake risk) through linking networks (i.e., the government and/or NGOs) commenced repairs and finished rebuilding earlier. Households that gained technical information (i.e., information regarding the materials and technique for repair and rebuilding) through bonding networks (i.e., neighbors and/or family members/relatives) also started repairs earlier. These results indicate that the provision of such information through the appropriate channels can lead to earlier recovery actions. By contrast, households that obtained financial aid information (i.e., information regarding subsidies and loans) were found to have delayed repair and rebuilding efforts, regardless of whether the information was obtained through bonding or linking networks. Surprisingly, the delay of completion was found to be larger in households that obtained information through linking networks. This delay was attributed to institutional problems, including complicated administrative procedures and delayed government action. The payment procedure for the subsidy, which was disbursed in stages during the reconstruction process, was reported to have several problems, which may have made it difficult for households isolated from financial markets and government support to navigate the procedure. We highlight that such problems hampered access to money and therefore the delayed realization of recovery actions, which in turn affected the completion time of the rebuilding process.

The findings of this study should advance the implementation of more effective information provision methods and institutional design to accelerate the autonomous recovery activities undertaken by disaster-affected rural households in developing countries. However, some possible extensions and directions for future research remain. First, our models implicitly assumed that information was received immediately following the earthquake. As our analysis deduced the effects of delay in information provision, it would be worthwhile to more accurately investigate when information was received under each combination of content and channel (e.g., financial aid information provided by the government). Second, the study focused on behavioral aspects, and it would also be worthwhile to conduct a similar analysis focusing on psychological aspects such as the subjective evaluation of the recovery of daily life [58] to enable a better understanding of the recovery process from a diversified standpoint.

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Appendix A. Supplementary data

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