Friday Forum: Multi-hazard Fatality Estimation for Cascadia Subduction Earthquakes

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1h 29m 51s

Keith Porter 00:00:24
All right, welcome, welcome to Friday Forum Number 246. Today is October the ninth, 2026. This series is hosted by the Institute for Catastrophic Loss Reduction. We are Canada's leading source for disaster resilience knowledge. We work to make Canada more resilient to natural disasters. Each month, we present recent research related to that mission. I'm your host, ICLR Chief Engineer Dr. Keith Porter. I am speaking to you from London, Ontario, traditional lands of the Anishinaabek, Haudenosaunee, Lenapewa, and Atawandan nations. Last month, Dan Shrubsoul told us about flood information sharing and mapping. He said that flood maps don't seem to affect land value, but homes in the regulated area can take longer to sell. You can find the video, slides, and transcripts at www.iclr.org/workshops. Next month on november 13, 2026, we'll be joined by Dr. Mahmoud Fiazzi from the Disaster and Emergency Management Programme at Royal Rhodes University. He's going to talk about how Quebec's post 2017 and 2019 flood relocation policy shaped unequal recovery outcomes in suburban communities. Today, it's my pleasure to say we are joined by Western University Professor Katsuichiro Goda. He will talk about tsunami risk in BC. He developed a probabilistic model to assess earthquake tsunami fatality risk in Tofino, Canada. Dan engineers commonly express fatality risk in the way that Dr. God is going to describe. It lets us label risk into four levels, from unacceptably high to negligibly low. So when Katsu says as low as reasonably possible. Later on in his talk, every engineer who knows that scale knows exactly what he means. I love the application of that labelling system to this problem, but that particular scale only talks about life safety. So I'm excited to hear about the integration of financial risk. A little bit more about our speaker. You have his bio sketch. Here's a little bit more perspective. Dr. Goda writes extensively on earthquake risk and stochastic simulation. He is one of our leaders when it comes to tsunami risk. On a more personal note, Dr. Goda is one of ICLR's best friends. He currently serves on our board of directors. We frequently draw on his work, and he recruits great graduate students who do great work. He is too young to be one of the grand old men of Earth engineering risk analysis, but only because of his age. Now, our agenda before our speaker begins. Here's our agenda. Our webinar will last 90 minutes. Katsu is going to present for about half that time. Then I'll moderate Q and A for the rest of the time, please feel free to chat your questions into the Q and A box-not the chat box, but the Q and A box. I will try to pose your questions in the order they appear in the Q and A box. If we have a lot of questions, I may only pose your first one, then I'll move on to others, then I'll circle back to your additional questions. Our webinar is recorded. ICLR will post the speakers' slides and a link to the video in the next day or so. So if you have colleagues who couldn't attend, let them know. You can find the video. You will be

able to find the video and all the other artefacts of today's talk at www.iclr.org/workshops. and with that, I will turn it over to Dr. Goda Katsu. Take it away.

Katsuichiro Goda 00:04:08
Thank you, Keith. So hopefully everybody can hear me. It's a great day, at least in London, Ontario. So I'm going to present my talk: the multi hazard financial risk and then the fatality risk estimation for Cascadia Subduction earthquakes. So I want to start as usual from the context and outline. So the Probabilistic risk quantification is essential for developing disaster risk management strategy to achieve a disaster resilient and sustainable community. So that's kind of my statement about what I do, my research, and then given that I'm going to present the summary of the multi hazard financial and then the fatality risk estimation for focusing on the one particular community in BC, Tofino, subject to abstract tsunami threat from the Cascadia Subduction mega thrush events in the Pacific Northwest, and in the specific topic. So first, I'm going to introduce this kind of risk tool that we have developed at Western, and then we're going to present the three specific kind of results. Hopefully, each of them are interesting from your perspective, disaster risk mitigation point of view. So the first topic is on the multi hazard risk assessment by distinguishing the contributing hazard sources in Pacific Northwest. So in these hazard sources, I'm going to include interface megathrust earthquake from Cascadia Subduction zone, but also there are crustal hazard and also in-slab hazard as well. So we integrate those three types of earthquake hazard into one. So that's the first topic, and in the second one is that the we developed the time-dependent aspect and tsunami hazard model and then risk model. So this time-dependent aspect, especially for tsunami, is interesting in a context of the climate change. So I'm going to integrate the time-dependent tsunami hazard and then also relative sea level rise effect into one risk framework, so that's the second one, and then the third one is that the as the title of this talk indicates, I'm going to talk about the frequency and the number of fatality, so-called FN carb for this Tofino. So this, I believe, that at least academically speaking, this topic, multi hazard risk quantification, is a very important topic, and then a lot of research has been done. So just that it's very timely that the aspect engineering and structure dynamics, one of the leading international journal, we just issued the specialssssket that the this topic is ofcn for many peoplesswallaws, and then you might have looked at or noted that the'ssbcn kind of news article, and then this article was written based on the paper I wrote, and then this headline kind of is like focusing on a very extreme situation, like Tofino BC tsunami study points to hundreds of deaths, and then also $1 billion lost. But of course we need to interpret those risk prediction in a proper context. This is a really extreme situation that could happen, but the most of the case it doesn't happen. But that kind of news article kind of caught a lot of attention by the media, other media, and also the public. So this might be a kind of broader kind of context of this talk today. So before I introduce details of some summary details of the the multi hazard risk model I have developed, first I want to take you at least Porter, to Tofino. So where is the Tofino? That is on the BC Island, BBC province, and then also it's on right on the Pacific, on the Bank of Island. So it's in

the middle of the Vancouver Island, and then this is on the this Tofino is on the Esowista Peninsula, and then it's known for natural scenery, sandy beaches, lakes, then wildlife, and then also in Asian rainforests, forests, and so on, so on. So a lot of tourists, in fact, the visit Tofino, but this beautiful place, you know, like this amenity, say like the nice features, comes with a place in a sense that there is a Cascadia Subduction zone, which could cause a significant shaking and also tsunami. So if Magnum Nine megathrust earthquake happen off the Vancouver Island, then the Tofino is would be one of the most exposed community in Canada, and also because it it's right on the coast, it faces the sea level rise effect over the next century, but nonetheless, it's a beautiful location. You can see from the photo nice beaches. It's nice to to walk around, and so on. So, so this is the the tsunami evacuation map prepared by the the district of Tofino. So that's official map, and then the there's a main Tofino town, which is in the north part. Yeah, so there's nice bakery, shops, hotels, beach, the arena. Like there's a lot of nice places to visit and hang around, and then those locations are typically above 10 metre. So I emphasise this 10 metre height elevation because the expected tsunami height in Tofino is about 10 metre, or potentially it goes up more than 10 metre, but up to maybe 50 metre. So if it's the the location is above 10 metre, more mostly the location is kind of safe or protected by by the high elevation, but these nice beaches, as we saw, so the beach areas mostly are below 10 metre, and on a map like that is indicated below 10 metre is indicated with this kind of orange reddish colour, and then but the the good thing about the Tofino is that the Tofino itself is very proactive. So it is difficult to see probably, but like here we can see the tsunami silent system. So there are four tsunami silent, so that the system, so that when the the aspect and tsunami happen, then the silent would ring, and then the evacuation process would started. And also, we can see many kind of signs for the tsunami evacuation to to get out of the inundation area, so the Tofino is at potential risk, but also very proactive in disaster risk mitigation. So a bit kind of more regional map of Tofino. So like it's also important to to put you know the more regional context, so there are four First Nations community. So it's not just the the typical kind of coastal city town Canadian coastal towns, but also there are Indigenous community people. So we have to protect both groups of people, and also the the permanent registered residents is about 2500 people in Tofino. But in summer, more than 8000 people alive, so the the total population exceed 10,000. So it's very crowded in summer months. So evacuation potentially can become significant issues, given that the roads are not particularly wide. So given that the some sort of overviews of the Tofino is given, so now I just briefly mention the influential hazard. So the the as I mentioned that the the one of the most significant source of hazard source is that the Megathrust seismic events from Cascadia Subduction zone, and then I'm skipping a lot of details, but there has been lot of research done from geological point of view and also geophysical point of view, and we have pretty much kind of identified that the many Megathrust earthquake happened over many years. So the the statistics we can cite is that, for example, the Golden Finger L from Oregon State University kind of identified that based on the offshore tabular history, 40 events over 10,000 years. So if we divide the 40 divided by 10,000, then the frequency average frequency would be one in 250

years. But especially for BC, which is the northern part of the Cascadia Subduction zone, only the full rupture case would reach the the significant kind of rupture in the northern part. So if we only look at the the BC, then that would be 19 events out of 10,000, so every one in 530 years, the the Megathrust rupture is expected. So that's a kind of the odds that we are we have. Then then the current sorry the previous the tsunami happened. This is kind of confirmed from various sources, but that was 1700, so 326 years ago. There was a magnifying nine event happened. With those kind of information, I kind of dig a little bit in to to model this recurrence pattern. So the typical kind of approach we can do is the time-independent aspect occurrence model using the Poisson model. So that's usually the standard. But when we look at the the history of the events, which is shown again here, then we can see some sort of clustering, and also the huge gap. So there's some sort of kind of irregular patterns happening. So I decided to model this sequence by looking at the the data uncertainty because those data are coming from the geological data, mostly based on the the radiocarbon dating of the the sediments. So there's a huge, large amount of uncertainty in each data point. So usually, plus minus 100 years difference is possible in terms of dated years for each event. So I took that uncertainty into account, and then I reconstructed many possible ASQ catalogue. and then obtained the the time between the the next event. So we constructed that this the interval time data from the geological observation. Then we fitted the the statistical model. So instead of Poisson distribution, we fitted the Gaussian mixture with the three components. So the three weighted combinations of the normal distribution, Gaussian distribution, constitute this kind of clustered and in the middle more regular recurrence, and in the large gap features. So that's the the model we developed. With this model, what we can do is that we can compare how this new research results are put turned into different tsunami and in the earthquake hazard level, so the the comparison would be usually against the time independent model, which is based on the Poisson distribution. So the bottom figure is essentially showing that the hazard rate, this hazard rate, is instantaneous occurrence probability given that the event hasn't occurred, non-occurrence. So, and then if we compare the the time independent model, that would be a constant. So that is why you see the black line is constant. But if we consider the time dependent model, which is in blue, then it gradually increases as the the the the the time since the last event increases, so we are currently at the 300 years or 326 years since the previous event. So then we are still kind of below the time dependent, so time independent model. But at the end of the this century, we would reach the time-independent model, and then we would continue to to exceed that. So our model can take into account this kind of time-dependent occurrence model. Also, the different aspect that we had looked at and incorporated into our modelling, it's the stochastic Labrador model. So, the twenting that the aspect modelling is judan bid by assuming that the the moment magnitude, the released energy, is kind of given, but the slip distribution tends to be uniform across the entire rupture zone, but for tsunami, this is no idea, or that's very unrealistic. So that has been kind of established in the literature. So we incorporated and we developed the so-called stochastic rupture model for Cascadia Subduction zone. So we first look at the 3d Subduction interface

geometry from the US GS, and then also we applied some sort of seismological relationship. I'm not going to go in detail for those models, but we incorporate those newest scientific results, and then we were able to now generate numerous stochastic laboratory model for a given magnitude, so this is just a kind of summary. I mean, the snapshot of the what this stochastic laboratory model would produce. So, given magnitudes about seven, 8.7, then those two could be the realisation potential stochastic rupture model. You can see that the slip distribution are different, but if we increase the magnitude, then the intensity of the slip and of course the extent of the large slip changes. So through this rupture stochastic rupture model, we can take into account this uncertainty, and this is very influential for tsunami hazard modelling. But those kind of stochastic model, but when they are summed over many realisation, it will reproduce the known kind of seismological features. So it's very useful and in the stable technique to capture the uncertainty in the the risk calculation. So I'm moving on to the the different type of hazard, inferential hazard. So the other source could be future relative sea sea level rise. So it's not my work, of course, but the lot of the global organisation and also national organisations such as the Geological Survey of Canada and Environmental Canada has produced the projection for the relative sea level rise in Canada. So this is just one results. So I refer to James A. O. from the Geological Survey of Canada. So they did excellent work on the isostatic glacial rebound estimate that is based on the local GPS data in Canada, because this postglacial rebound is important for Canada because that the the most of the the land in Canada was in the ICH. There was huge thick ice on top of the land, so our ground is still moving up to to you know adjust for this kind of heavy weight which is melted away, so that kind of effect has been already taken into account in a proper way in those relatively sea double rise future predictions. So that's a kind of movie of the the results projected by the Geological Survey of Canada, but now focusing on a particular location, Tofino. For our case, this is the GSC Geological Survey of Canada's estimate. So over the years, over the century, in Tofino, near Tofino, the possible sea level rise of 0.7 metre in the worst kind of situation, RCP represent the percent concentration pass, which is the emission scenario would reach. So we want to take into account not just the worst case, but also the uncertainty of those the relative sea level rise integrated against the tsunami hazard. So I'm going to show you some results later. Another things which is often kind of ignored potentially sometimes is that the tidal variation within a day. But the Tofino is excellent in a sense, that the they have tidal monitoring station available, and then that has a long record over the the next last century. So we have more than 100 years of data for the tidal variation. So these results are shown in the last 40 years or so, you can see that the plus minus within a day two metre tsunami sorry the tidal variation is possible. So if we ignore this kind of the daily or hourly tidal variation, then sometimes we underestimate or sometimes we overestimate the tsunami hazard. So we took this daily, hourly tidal variation into our risk assessment. So now I'm moving into just introducing the the the tools that we developed. So I call this as a multi hazard risk assessment framework. I I adopted the the typical aspect dynamic approach. So, in principle, risk is equal to hazard times exposure times vulnerability. For Cascadia, what we consider is that the

earthquake occurrence model. So, I mentioned about the linear time-dependent model. I also showed the the stochastic rupture model. So we model the aspect slip as a random field. So this those two parts serves as a common effect, yeah, on the ground shaking and then also the tsunami inundation. Once that common effect is captured, then I proceed to do the ground motion modelling using the ground motion model, statistical model, and then for each individual house, I can estimate the ground shaking and then apply the seismic vulnerability function to estimate the degree of damage given a shaking. I can also do the same, but solving the different types of equation to estimate the tsunami inundation, and then once the tsunami height at the given property, then I can estimate the the degree of tsunami damage, and then once loss or the fatality is estimated for both seismic and tsunami. We can combine those as a multi hazard risk estimate. So this is only for Cascadia, but as I mentioned, there are other types of seismic sources. So we also take into account crustal and an insular earthquake, and for this case, crustal and insular earthquake usually don't cause significant Tsunamis, so only goes into ground motion watering. And I also mentioned the relative sea level rise and then also variable tide, so that goes into tsunami. So I consider all those components in the modelling framework. So I just show kind of really a snapshot of the earthquake risk assessment for non-ts tsunamic genic. So this is applicable for crustal and inslav events. So I took the the national seismic hazard model from the developed by the Geological Survey of Canada. So the model starts with the aspect catalogue, and then the seismic source zone. Apply the ground motion model to, and then we develop the stochastic event set, and then by doing the somewhat simple statistical analysis, we can come up with the ground motion hazard curve at the interfino, and then we can also do the disaggregation results. So this disaggregation results, which is shown here, kind of essentially shows that the the large Cascadia Subduction zone is very influential for the very large or the rare extreme situation. So, if the ground motion level is 0.2 g, then crustal and inslav aspect contribute. But the as the ground motion level increases, then majority of the contribution comes from the large Megathrust Cascadia Subduction zone. So that kind of example kind of clearly shows that the the model in the Cascadia Subduction zone very important. With that, the non tsunamicogenic aspect hazard and risk modelling. We also need the building exposure data. One of the reasons that I spend a lot of time in modelling, developing the the tsunami risk and in the earthquake risk model for Tofino is that the the availability of the high quality data. So the the district Tofino kind of did the building by building survey, and then all the building hookprint, construction age, material type, values, etc. are all available. So we took into account 1700 89 buildings, all the building in Tofino, and also the the local site information BS 30 value is available based on the local microzonation work that was commissioned by the district of Fino. So that is great. So we can see you can see that the BS 30 value is low, which means it's higher site amplification in the beach area and in the the downtown area is at the the rock side, so the amplification is low. So that kind of local information is available, and then we can also have material information, construction year information, height information. All those is available. In Tanner. the exposure and hazard data into the risk vulnerability data. We used a seismic

fragility curve developed by the NRC can, and also for tsunamic fragility curve that was not available for Canada. So I took the tsunami fragility curve I developed from the 2011 Tohoku Earth data. So those are the exact the vulnerability curve for seismic, and then the tsunami fragility curve for tsunami. So those are the curves exactly I used. So once we have those exposure and the the vulnerability component, then we can integrate to obtain the probability distribution of the tsunami or the seismic risk. So in doing so, especially for Cascadia, so this is specifically for Cascadia. So then, like we start with the stochastic raptor model, which I showed in the beginning of this presentation, and then we run the tsunami Inundation simulation in a high resolution, five metre resolution, so which is pretty high, and then we can for each rupture, I can get the tsunami Inundation in space and in time, and then we also have a good exposure data set, and we also have a tsunami fragility model for individual building. So once we have Inundation exposure data vulnerability, we combine to estimate the loss for each location. Then we repeat this for many cases, many rupture cases. After that, we can obtain the probability distribution of the tsunami loss given a particular magnitude. Now, with those information, we can combine everything into one. So we start with the occurrence model, so that's time dependent model, and we also take into account the tidal variation and then also the sea level rise information, and then we also take into account that the tsunami risk, a conditional tsunami risk probability distribution, which is mentioned in the previous slide, and then we because we do the time-dependent analysis, we can develop the stochastic catalogue from the time-dependent analysis, and then numerically we can obtain the tsunami and then also the earthquake hazard curve by taking into account all the model uncertainty. Later, so I'm going to also mention about the fatality risk. So let me just give a little bit more details on the the fatality part. So population exposure model, the Tofino also did the survey. So we roughly know that how many people lives at the particular location, and they also have peak summertime distribution and also the the peak summer by the night and then the daytime distribution. We also had the information about the tourist kind of information to obtain the annual kind of profile of the people in Tofino. So we combine all those, and in addition to this population exposure dataset, we apply the fatality rate model. So, given a shaking, then what would be the fatality rate? And then, given a tsunami flow depth, what would be the fatality rate? So, this is for earthquake. This is for tsunami. You might note that the just numbers are very different. So the the shaking Tsunamis fatality rate is maximum maybe about 2% That's based on the NRC cans data. The tsunami fatality rate in the worst case could be on average as bad as 20% Those 20% you might think that this is a very extreme, but like for the very specific community, we did observe that about 15% of fatality rate in a particular community in Japan after the 2011 Tohoku earthquake. So those models are based on the empirical data, but not for Canada. So there's a moral uncertainty in applying this Japanese model into Canadian context, but there's no other model that we can apply. So quickly, I want to go through three types of three sets of results by applying that the the model I mentioned. So the first the topic is that the multi hazard risk assessment by distinguishing the contributing hazard sources. So in this context, Megathrust earthquake, inslav earthquake, and then a crustal earthquake, and also

both shaking and in the tsunami. So if we do this kind of analysis, then this is what I've got for the. So this is the aggregate loss for the entire 1789 building in Tofino. So the total asset of the the building is roughly about $2 billion on the market value, so that's the the exposure data set developed by the Tofino indicates. So with that, this curve shows essentially the Exceedance loss curve probability curve for different types of hazard. So black is multi hazard, blue is the non Cascadia, so crustal inslab on shaking only, and in the green is the Cascadia shaking, and in the red is the the Cascadia tsunami. So if we look at these figures, then the what we can see is that the from shaking point of view, sorry, the the sorry the the multi hazard loss point of view for the entire Tofino, the shaking risk dominates because more or less like this green curve is more than factor of two difference or significantly larger than this red curve, so the multi hazard total risk is mostly contributed by the shaking risk. So the shaking risk is important components, but also we can see that the the tsunami is non negligible, and then I saw that this results might be kind of a bit biassed because I only consider the the whole Tofino as a one kind of community. But if we divide the exposure data set into two parts, one in the the low lying area, so essentially near the beach, which is shown in red, and then blue, which is above the 10 metre elevation. So if we split the total building into two groups, so then roughly it's 5050 kind of spread. Then if we develop the risk curve for each group, then the results would look like this. So the in this graph, that the dotted one is that the this low elevation building. So if we do that, then like of course the shaking risk is more or less kind of uniform across entire Tofino, so it would be essentially halved because the building size, exposure size, portfolio size has been halved. But the the tsunami risk obviously in the low lying area doesn't change between the solid curve and in the broken line. So essentially, of course, the tsunami risk is concentrated in the low-lying area, and then the tsunami risk and then the shaking risk from Cascadia Subduction zones are more or less comparable. So that kind of results would give different kind of perspective. Like in the low-lying area, Tsunamis and shaking are both important and almost equal in size in magnitude, but like overall, the shaking is more dominant because that affect the the building at the higher elevation. So this kind of local or the divided view of the risk might be very useful, especially for the insurers and so on, for the rate making or the premium rating calculation. This tool also gives additional kind of tools that doesn't didn't exist before this tool. So, for example, we can still do the full Probabilistic risk assessment, but we can link back to the particular scenario. So, for example, we can develop the joint multi hazard risk and hazard map for a given return period level. So, this is developed for 1000 year return period. The critical scenario might look like this. Shaking intensity might look like this. Shaking damage might look like this. Inundation might look like this. Inundation loss might be this, and then the multi has risk. So this kind of results might be useful from the city planner's point of view. We can also change this return field level to a different probability level. So, for example, if we go higher, more extreme situation, then the picture might look slightly different. So, the the tsunami potential earthquake rupture critical scenario might look like this. So, you might note that the slip has moved closer to Tofino, so which is kind of expected. Then the shaking level, of course, increased, but also the tsunami increased

significantly. So that led to the almost equal or the more dominant the risk from Tsunamis. So that kind of information is useful. Now I'm moving into the second part, so in the second part of the results, I'm going to show you some effect of the time dependent, but focusing on the tsunami hazard, and I also integrate the tidal and the relative sea level rise effect. So this is I haven't included yet the sea level rise effect or the tidal effect, but this is purely based on the tsunami risk by considering the mean sea level condition, but considering the time dependent tsunami. So over the century, as I showed in the beginning, the the occurrence probability increase gradually increases, so like this figure essentially shows that if we wait longer over this century, then the how the tsunami risk curve for Tofino changes over the century. So the blue corresponds to the beginning of this century, and then the 2100 corresponds to the reddish. So, roughly factor of two increases is obtained over the century. So that's the tsunami risk, and then this rate of increase would accelerate in the the 22nd century. Now I want to just show a kind of illustration of the how the tidal level is impactful. So the as I showed in the beginning, the tidal level within a day, even now, might change plus minus two metre. So if we have some specific tsunami scenario, but assuming that tidal level is on average zero metre, one metre, and then two metre for the same aspect scenario, this is the difference. And then I show in BDF on the right more extreme situation. So what I want to convey mention here is that the well the tidal level if you know zero metre one metre two metre two metre is possible within a day but if that high tide and coincide with the significant tsunami the effect could be non linearly inflated or the amplified so you can see visually that how amplified those effects are. So with this kind of in mind, then I essentially repeated a lot of Tsunamis simulation with the different tidal condition. So I consider zero metre, one metre, two four metre, and then for many different aspect scenario, magnitude 8.7 to 9.0. I developed this risk curve, which by following the procedure I showed in the beginning, and then we integrated these results into tsunami risk. So now we can take into account the time dependent tsunami risk with the tidal effect, so this result essentially shows the the how the tsunami time dependent tsunami risk changes over the years when we consider sea level rise effect or not, and then in each panel, this black I mean the dot doted lines are based on the time independent hazard model. So those dotted lines are the same in each of those four figure panel, but those red and blue lines are from the tidal sorry time dependent model. So that changes as the elapse time increases. So this is more or less current. This is about 25 years later. This is 50 years later. This at the end of the century. So you can see that the query that the the tsunami hazard or the risk level is below the time independent model, but it gradually catch up, and then by the end of the century, it would be almost equal. And then as we progress, the time tsunami time-dependent tsunami risk would exceed time-independent risk estimate, and so on. And then we can also capture the the effect of the different climate scenario, for example, so representative concentration path pathway. So if we do the similar kind of analysis, but for individual civil rights scenario, currently the different, you know, the RCP scenario doesn't change significant at all, so that's in red. So there's actually nine curves shown, but the essentially all nine curves are essentially the same. But as the time goes on, then the effect of the the crime scenario becomes more significant. So

we definitely need to take into account this kind of uncertainty in the future scenario. Now I know that my time is kind of running up, so I'm just going to focus on. But this is the the main part of today's topic. So this is the application of the developed model tool for shaking and tsunamic fatality risk estimation. So, as Keith mentioned in the beginning, there's a lot of work has been done, especially when it comes to the disaster risk management, because disasters are considered to be involuntary risks. Yeah. So, like, and then we also have to take into account kind of societal perspective because those are sometimes regulated or the the protection is controlled by the government through, for example, design code or some sort of typical engineering practice in place in our society, so a lot of work has been done. One of the thing has been done lead is the Netherland and also the UK, and they have developed some prob the the scheme for the risk management purposes. One of the the famous one is the as as low as reasonably practicable ALARP criteria, but this ALARP is usually applied for the individual risks. But when it comes to the natural disaster like earthquake and tsunami, we need to consider the group risk. So in that context, we typically apply so-called FN curve. So fatality, a number of fatality versus frequencies. The frequency is on vertical axis, and then the number of consequences is on the x-axis. And in those lines, kind of divide the risk management area. So, as Keith mentioned, if the the number of fatality is low, and then the frequency of such kind of incident is low as well, so then that's negligible risk. On the other spectrum would be the really frequent loss, and then producing high number. So then that's obviously unacceptable. But there's some sort of grey zone between, and then those grey zone are typically considered to be ALARP region. So if the risk falls into the ALARP region, the general recommendation is to try to reduce as long as that it's cost-effective or the reasonable solutions are available. So we run a multi-hazard fatality risk simulation for all the stochastic event, so it's very similar kind of example, but our model, our framework can do the given as quick lecture. We can estimate the shaking at the given location and also Inundation. And for each location, assuming that the the people are inside the house, then we can apply the fatality rate to estimate the the shaking fatality, and also the tsunami fatality, and so on. So those are the particular. If this happen, then potentially at those coloured location, 14 deaths could be produced, generated. The same situation could lead to up to 200 potential fatality due to Tsunamis. So those are just the estimate simulation results, but we can repeat this simulation many many times. So if we do this calculation, this is what we get. So this is again formatted in a presented in a FN carb format. So again, annual frequency of n or more deaths, and then we have a multi hazard model, so we can do the fatality estimation for non Cascadia shaking only, Cascadia shaking only, and then the Cascadia tsunami, and also the multi hazard, and then we can compare that against the several kind of lines. So this Negligibility line. So below this, like we don't really should have to concern about the the risk mitigation any any longer. If the curves in this top right corner, then that's unacceptable. But the the Cascadia Subduction shaking green and then the tsunami red are in the Alapp region, which is the region between those three four dotted lines. So, with this in mind, of course, the you know that we well obviously the tsunami risk is more than shaking risk. So that is kind of reverse situation. If you remember the the case

for the financial risk, so the financial risk earthquake risk was higher or at least equal, but the tsunami risk was equal or less. But the the situation has been flipped essentially, so that's important. So the in terms of fatality risk management, Tsunamis is important risk to mitigate, and of course, there is multiple ways to to reduce. One of the solution could be to construct the vertical evacuation structures so that the the people in beach area can get access to high and strong structures so that the you know the the wave can pass and but still withstand the tsunami waves. But now if we compare that with the financial risk curve, so this is the exactly the same slide. I mean the results I showed before, and then I show the previous like fatality risk. Again, this green, red, green, red are flipped. So again, shaking is dominant in financial, but the less dominant in fatality, so that's interesting aspect. But when we combine the shaking risk, Tsunamis risk, and multi hazard risk in terms of number of deaths and in the catastrophic loss, then very complex kind of multi hazard risk distribution can be obtained. So I, my, my, I don't have any particular kind of solution how to manage this multi hazard risk from the Cascadia Subduction zone. But I think that the at least the what I can say is that the we should go consider both shaking and in the tsunami risk, and we should also consider both number of fatality or casualty and also the financial impact because both criteria, both metrics are important for disaster risk management. So with that, I just want to briefly mention that where I'm going in the next hopefully a few minutes. So, well, those are just one of the application of the so-called cap modelling approach in a context of the community disaster risk mitigation. Once we have this kind of tools, then we can apply various kind of we can consider various application. Obviously, one of those would be the multi hazard risk mapping, but also we can apply for the response phase, recovery phase, and the mitigation phase. Whole cycle, whole phase of the disaster cycle approach. So that's the kind of the direction that our group is taking at Western. In particular, what we are trying to do these days is to to have a better, more efficient tsunamic early warning system, and also the evacuation and then the response, at least through some sort of modelling side. So the dynamic risk quantification for population and assets in community across the community is an open research area, so that's the direction we are heading to. So the one of the reason why is to how to optimise the available nearshore Tsunamis early warning system. So we have NOAA's offshore buoy system, which is called Darc system, and also Ocean Network Canada in BC in Victoria has installed the ocean bottom sensors for tsunamiari warning system. So those locations are shown near the Cascadia zone. Those are the NOAA point, NOAA location, and then those four are the ONC Ocean Network Canada's site, but we could potentially instal several new warning station to enhance or to make it efficient. So we can use the stochastic tsunamic scenario because we have 1000s of tsunami estimation runs, and then we can use the machine learning model to learn more effectively how to make a prediction, how to issue warning messages. So that's the kind of the direction we are trying. So we try to optimise that the tsunami audit. warning system using the LSTM long short memory short time memory neural network model to optimise the system. So we have just published those work, and then also we are looking at the the load capacity of each segment of In Tofino from pedestrian point of view and also the car point of view. So that

is one activity we are doing. We also gathered the population data from the terrace mobility form, mobile form data, so that led to a new kind of ideas of the dynamic risks. So instead of one snapshot in the summer peak time and the census based information, we now from the terrace data this population changes weekly, daily, and then more kind of seasonally. So this kind of information leads to a better population modelling for the nighttime, daytime, and transition time for residents and non-residents population. So we can then we can get the spatial distribution as well for each time instant. So then we can do dynamic evacuation modelling. So this is not dan for Tofino, but that's a future direction. What we want to do, we did the similar work for Japan, focusing on the similar coastal community. So in this coastal community, which is called Saga District, they actually built evacuation tower at this middle of the the community. And then in the past, we did. Suppose we like some sort of agent-based Tsunamis simulation should run, but essentially what we want to do is that we can model individual population in the town, and then we put the the Inundation tsunami scenario to to see that how people would evacuate within a community, and then we can come up with the better mitigation measures, such as construction of the vertical evacuation towers for the case of Tofino. So that's the direction that we want to go, and then all the information get we get from the morbidity data, and then the fatality risk model would be all important. So that's the direction that we want to go. And then that is all I wanted to say today. So thank you.

Keith Porter 00:57:16
Terrific! Thank you so much. It was very interesting talk. Let our attendees sort of gather their thoughts. Of course, I have lot and lots and lots of questions since we're kind of in the same business and at least in related businesses. And so, what you were talking about really resonated for me. So let's start at the at a very very high level, you presented the FN curves, the relationship between the number of people who might be killed and the the frequency with which that number of people are killed. That was the space that was divided into four or five zones, depending on how you count them. Let's step back from that. Tell us about the life safety risk to a resident from these earthquakes compared with, say, automobile accidents, heart disease. How risky is our Tsunamis? How big a risk is our Tsunamis to the life safety of Tofino residents compared with these sort of more day-to-day perils.

Katsuichiro Goda 00:58:25
Sure. So, like, if it's an individual risk, like if it's if we focus on one particular person, right? Yeah. So then, like you know, like the typical kind of approach we do is that this ALARP kind of invalid triangle, and then like we typically take that 10 to the minus five of six as a kind of a reference point for the acceptable risk, and then 10 to the minus five of three as a kind of too much risk. That's kind of leading to more like an voluntary risk in a sense that the people might do mountain climbing or like a mountain biking or like some sort of voluntarily do some dangerous activity, and then the 10 to the minus power of six usually linked with some sort of a lightning hitting or like some sort of a car accident or some general risk that if we live, then

that's the risk kind of we accept but we don't care, right? With those two anchor points, then like if it's individual person interfino, then that is definitely in that tolerable risk or somewhere around here. Partly because that the this Cascadia earthquake only happens one in currently in 1000 years, so that's already at this level, and given that the huge aspect happened, what would be the chance that the person, particular person, might be killed? That's probably less than 10% probably a few percent. So then, like that, goes to 10 to the minus power five, right? Goes 10 to the minus power of three times 10 to minus about two 1% so that comes around here. So if it's individual, that probably is very close to acceptable risk. But when it comes to the community level, the the the things that we need to pay attention is that the earthquake tsunami, the loss is concentrated spatially, so then multiple people might be killed. So that is why we care about this group risk, and then we use not just this triangle, an invalid triangle, but we use FN curve to capture how many people might be killed in a particular incident. So the Tofino's case again might goes to if it's a really rare case, 100 people might be at risk. That's about 1% of the whole population, but that is well within high close to the higher end of this ALARP region. So, if we consider the group risk, like which is here, the bottom of the term, this ALARP region would increase to higher end of the ALARP region.

Keith Porter 01:01:16
So, so basically, I mean, I'm going to sort of reinterpret and tell me if I'm correct. If you were a resident, you shouldn't. If you're a resident and sort of concerned about yourself, your own personal safety, your own, you know, the safety of your family, would you tell that person, you know, this is this is a thing that could happen. It's a lot less likely than you getting hit by a, you know, hit by a car in an automobile accident, or or killed from heart disease or something like that. But that it's a much bigger deal, something for you know for policymakers to consider to to to be worried about because heart disease doesn't kill 100, 1000 people simultaneously in a single event. Is that about correct?

Katsuichiro Goda 01:02:06
Yes, that's that's my take. And then, like, well, I mean, you know, like the tsunami risk. Like, we there's so much we can do to to reduce the risk by ourselves. Like, some Tofino's case is slightly different, but for example, I have a lot of result. I mean, the the cases from, for example, Japan, right? And then, like you know, like whether they build try to build some sort of embankment to protect the city or the sea wall or like a offshore kind of breakwater or something like that, then that's kind of community risk. Like so, like whether that exists or not, or the evacuation tower as well. You know, like we cannot construct such kind of infrastructure. So then the decision becomes more like a community level or the municipality level or the even the provincial level, and then we need to do this kind of cost-benefit analysis, as you know, you're the expert on that. But also, we need to take into account the fatality risk, and then the the decision would be, I believe, that would be corrective, the community level. In that sense, I

think that that this kind of number, a simultaneous number of fatality, is a kind of one of the key aspect. Yeah,

Keith Porter 01:03:25
that that's why we have that. That's why the dam engineers created that. I think it was from dam engineers. That's why they created those curves. Another sort of high level question. You know, you alluded to the fact that crustal earthquakes don't cause Tsunamis, but this these offshore earthquakes do. Do you want to explain for people who don't, you know, are not quite as familiar with the physics of earthquakes? Why do these offshore earthquakes cause Tsunamis that other kinds of earthquakes don't?

Katsuichiro Goda 01:04:01
Sure, sure. So, well, like the I I think like you know like in elementary school and so on. So I did the the one of the you know the video making for the CBC kids. Like we know that when the the huge ask happen in the middle of ocean, then the you know the amount of the slip that we expect, like from the magnitude nine, and then that is based on the our kind of experience, is about 10 metre. So the 10 metre of the water would be lifted, and then by gravity that has to go down. Then that becomes a wave, right? And then the the Cascadia Subduction zone, which is kind of indicated in this kind of grey area, if we look at this, like that's kind of 1000 kilometre and a couple of 100 kilometre width, if you know the 10 metre volume and then the offshore is about three kilometre in water depths, if huge amount of volume of water is kind of lifted, then that causes Tsunamis. So that is why you know the tsunami becomes large. The other things like you mentioned is that the for Tofino is very unique location because it's very close to to Cascadia Subduction zone, but when it comes to the the crustal seismicity in BC, more active region is close to Vancouver. So if it's in Vancouver, the crustal and inslav earthquake is more dominant. But in Tofino, as you go towards the ocean, the crustal and inslavascular risk decreases. On the other hand, the Cascadia interface risk increases. So that is another reason that the you know the Tofino is kind of very unique case.

Keith Porter 01:05:56
Let's talk more about what government is doing to protect people from the the life safety risk. You showed evacuation route signs. What else is the BC Ministry of Emergency Management and Management and Climate Readiness doing? What else is the federal government doing, if anything, to to protect the residents from tsunami risk.

Katsuichiro Goda 01:06:24
Sure. So, like, well, the one of the thing is, of course, obvious kind of solution is the physical risk reduction, and then that can be probably only be done through the construction of the vertical evacuation structures in the context of Tofino because they don't have a high ground nearby in the beach area, so that's how it is. But I think that the Tofino is also very active in the the

training. So like the BC government do annual ground hike up. I'm not quite sure that my my memory is not accurate, but like there's an annual tsunami evacuation community exercise event, and then the Tofino kind of signed up and then organised the annual event for that. So the the tsunami hazard and risk awareness is definitely an important one, and also I'm aware that the the tsunami sorry the emergency managers in Tofino are very keen and very aware of the tsunami risks. So, and also they are aware of the population difference, residents versus the tourists. So, they are actively trying to educate people, residents, and also the tourists through this kind of ongoing capacity building activity, and then also trying to come up with the disaster recovery and also the response planning for the emergency, so that resonates well with the what you know the initiative done by the ICLR by Sophie, etc. So, so the Tofino is yeah the the community who are keen on those kind of soft aspect of the the Tsunamis mitigation.

Keith Porter 01:08:11
Do you think that you're going to find that Tofino needs evacuation towers? That you're going to find that they would save a lot of lives compared with just getting people to high ground.

Katsuichiro Goda 01:08:25
They consider my understanding is they consider those as an option, and then some sort of preliminary kind of design work has been ongoing. That's what I know, but they haven't yet decided whether they construct partly because of the availability of the land and so on.

Keith Porter 01:08:48
You you talked about the beginning of your talk. You said that there would be like warning sirens when an earthquake happens. How automated is that? How reliable is that? Is it would that that process that leads to sirens going off? And if if I had a friend who was vacationing there, how confident that I could could I be at the moment that they would be warned, that they'd hear a warning signal and know what to do?

Katsuichiro Goda 01:09:18
Sure. So well, I mean, so the you know once the signing is off, then like what to do? That's the education part. And again, the Tofino emergency managers are very keen and active on those kind of public education, etc. So that I'm gonna set that aside. I wasn't in. I mean, like when I was in Tofino, like you know, there was no actual signing. I mean, the the the signing kind of you know went off, didn't go off. But like like there's always kind of a system testing. So when I was there, like they regularly tested the system, and then also they are linked with the the international. I forgot the the name of it-but like a national and an international tsunami warning system. So they kind of automatically get the warning. The the several issues I've heard from the people in Tofino were that the in a good good way there was kind of false alarm for the actual tsunami event. For example, two years ago or something like that, Kamchatka earthquake, which stroke struck in Russia, and then they the the the silent went off, and so on.

So it was too early, like you know, it wasn't significant risk, but like the sighting was off, so the people weren't happy. But you know, they made an error on the safer side, so I think that's at least good. Of course, if we keep repeating this false alarm, then the people, you know, the crying wolf kind of things, you know, the people get frustrated. So of course we have to make you know the system reliable. So that yeah.

Keith Porter 01:11:06
Um, how much of sorry you may have told us this, but I might have been typing at the time. How much advance warning do you get if the if there's a Cascadia event right near Vancouver Island?

Katsuichiro Goda 01:11:21
So well, I mean, we do have a well tsunami simulation based result. So that's model based. So I put the this kind of warning on that. But like the typical kind of warning time, like from the start of the shaking in model domain, would be like a 25 minutes to 30 minutes? That's a kind of typical for the Matia 9, but it could be as low as like as soon as 10 minutes.

Keith Porter 01:11:50
Okay. So yeah, yeah. 10 minutes. You feel the shaking. So this is 10 minutes from the time you feel the shaking to the time you have to be at high ground. Or is that 10 minutes from the time you get a warning? Well, I guess there's only a few seconds between the time that the shaking, but early earthquake early warning is only going to add a few seconds to that, right?

Katsuichiro Goda 01:12:08
Yeah. So the 10 minutes after they feel the shaking.

Keith Porter 01:12:12
After they feel the shaking. Yeah. Okay. Now Tsunamis in the deep ocean they travel really fast. I mean, real fast compared, you know, sort of compared with the speed at which the the seismic waves travel. So the seismic waves. Could you tell us basically how fast the seismic waves travel? Those are the things that you're going to feel when the ground starts to shake versus how fast the the tsunami is approaching, so you know, way off the coast there, the earthquake happens, and it's kind of a race between the seismic waves coming through the Earth's crust and the ocean wave that's coming towards you. So there's, you know, you get the the dis the difference in the the speed of those two things. Can you tell us a little bit more about that?

Katsuichiro Goda 01:13:02
Sure. So, well, I hope like I don't say a wrong number. I don't have a number on my hand right now. But like, you know, the the typical number we cite, for example, seismic like P wave and S

wave, right? So then, like the P wave, say six kilometre per hour, kilometre per second, sorry, to eight kilometre, and I think that the usually the shear wave, which is the you know the the usually the stronger one, is that the roughly three to four kilometre per second. So that's the the seismic, right? And then the the tsunami is significantly slower. So in that same unit, the tsunami is usually 0.2 kilometre to zero point maybe five kilometre per second. I think something like that. So that's a speed just slower than the the aeroplane, depending on the the the yeah the depths at the wave, yeah.

Keith Porter 01:14:03
So, so it's not that much of a race. The the the the seismic waves are like 10 times faster than the ocean waves, so it's not that big of a deal. Let's see. No questions yet. Can you tell us how loss was broken out in the Tohoku earthquake between tsunami damage and shaking damage, and whether that's whether you're seeing. Would you expect the same sort of thing to be the same or different in Tofino?

Katsuichiro Goda 01:14:37
For from Tohoku, like it's a bit difficult to say, partially because that the like there's no official statistics that distinguish like this is from the seismic and then this is from tsunami. Like you know the coastal areas like probably are affected by shaking first and then some damage might have happened, but the large tsunami came one hour later or 30 minutes later, and then everything's washed away. So there's no kind of significant major evidence to distinguish those effect. But I think that the the probably the story is that the the ground shaking. I might be wrong. Like probably GSC, you know better than me. But like you know, shaking like you know the the building like a like a the pancake collapse or like a significant destruction like of course happens but like a you know like a the shaking has to be very large like a 2g 3g and something like that then that kind of complete destruction could happen. What we saw in Tohoku is that if you have like you know three metre height like a massive tsunami wave, then like majority of the wood flame building will be simply washed away. Like not necessarily the wall etc. but like the foundation is not kind of anchored properly. I mean not strongly, and then like the sheer volume of water pressure, like a hydrostatic, hydrodynamic force is simply way significant.

Keith Porter 01:16:09
Yeah, yeah. I mean, that was my impression that in places that weren't near the seashore, the buildings had, from the outside, very little visible damage. You know, inside it could be a different story. You break plaster, and you can be talking about 1000s or 10s of 1000s of dollars for sort of a house size building. But the the the the so the average shaking damage in that what's what's the name of the plane that was pretty much washed clear, where all you saw was these piles of debris and all the houses were knocked over. That was just 100% lost to 100% of the the buildings. So probably my guess is that you know if the if there had been no tsunami, there might have been, you know, point 1% loss in that plane in terms of you know

fraction of the repair cost is a fraction of replacement cost new maybe point one or 1% but because of the Tsunamis, it was like 100% Is that was that your impression as well,

Katsuichiro Goda 01:17:21
yes.

Keith Porter 01:17:22
Yes. Let's see. Still no questions from our audience. What you you talked about ice on top of of the land weighing the crust down. Do you want to sort of explain that more more physically, how I mean, it might surprise people to know that retreat of glaciers matters and why that might be. Could you sort of explain the the Earth's crust, the weight, how much the weight of glaciers compares with the weight of the Earth's crust, and how the Earth's crust rests on top of a mantle.

Katsuichiro Goda 01:18:04
Okay, so I I'm not the expert. I'm just citing the the results, but like my understanding, like I think hope at least the the ballpark kind of bodies I mentioned is correct. But like the the thickness of the the the ice could have been like a kilometre range, so then like you can imagine that the you know thickness um so then like that if that melt away and then like a the soil doesn't respond like a uh you know it's a kind of creep kind of situation so like it would gradually go back and then like we do see that the rebound in the GPS measurement. So those red, for example, James all the the GPS location. Those are the GPS location, and then you can see that depending on the location, like we see a millimetre per year kind of rebound uplift or sometimes like a few three, four millimetre per year rebound. So, so I believe that that was the how heavy it was, and then when melt, you know, so that the time since the melt is also especially different. Yeah, but that's the kind of the overviews of the the what is happening at the moment.

Keith Porter 01:19:26
Yeah, as I recall, it's I mean, so something like a kilometre of ice sitting on top of what's the thickness of the crust over the you know continent of North America is it 25 kilometres or is it 40 kilometres something like 25? So it's like 25 kilometres of rock overlain by a kilometre of ice, and of course the rock is denser than the ice by, I don't know, like three times or something like that. So it's I guess that would be something like one on the order of a 1% decrease in the weight of the the crust sitting on top of the mantle, so it's basically you know the the the the crust sort of rises up because there's less weight pushing down on it, and it's sitting on this sort of semi fluid thing called the mantle, so it's it's actually flexing. It's it's changing its shape. The that ice weighs enough to change the shape of the Earth's crust, and as that slowly undeforms, it releases stress. Am I getting that about right?

Katsuichiro Goda 01:20:37
I think so. Yeah.

Keith Porter 01:20:40
Okay. Let's see. You stopped your your analysis kind of stopped at magnitude 9.1 upper bound for the Cascadia Subduction zone, and I and I remember many many years ago, we talked about Cascadia events potentially reaching magnitude 9.3. Is that 9.3 figure old or out of date or is it wrong or does it not matter?

Katsuichiro Goda 01:21:16
No, no. I mean, like I think a magnitude 9.3 could be the upper estimate, and I think that's valid. So, for example, I think the US GS goes to that range. I think like I'm more like focusing on the the geological side of Canada. Yeah, but like more, I sometimes like a very very hesitant to to go beyond 9.1, partially because that the sum of the the model we use is highly nonlinear, and then we don't really have that data, and then so on. So that there's some sort of practical reason that you know I have some sort of fear factor that okay, well I don't want to go beyond that my comfortable range. So that's why, and the magnitude 9.1 is a reasonable estimate. So, so with those situation, I, I that that's how I stop. But okay, definitely we can go beyond.

Keith Porter 01:22:16
Makes sense, and and the difference between a magnitude 9.3 and a magnitude 9.1, just I did it on my calculator. There, it's about double the energy release because earthquake magnitude is a log scale. Okay, let's see. Do you want to? You you used some terms of art that are really really familiar to structural engineers, but may not be quite so familiar. You explain them. You explain what a hazard curve is and what a fragility curve is. But you you want to sort of at a big picture level say what a hazard curve is and what a fragility curve is and how those two things go together to quantify risk.

Katsuichiro Goda 01:23:03
Sure. So the hazard curve is something like this, right? So this, so that integrates that the when how frequent earthquake happen and the way happens, and then the if it happen how large the ground motion shaking, and then those kind of frequency etc. weighted properly, then we produce this kind of curve. So if we go rare situation, then the expected ground motion level will tend to increase. Then that's kind of exponential. That's we usually call the hazard curve, and then we use this for the seismic design of the building, specifying the hazard level for each location, so on. The flagitary curve will typically what is or Keith, you're the expert on this, but we have usually called this is we call this as a vulnerability curve, and that's a mean vulnerability curve. So, given the shaking, then what would be the mean loss ratio for a particular group of building? So that's the mean value, and then I didn't mention that, but I got for each individual building, I added this additional uncertainty on top. So that's usually the the vulnerability curve.

Fatality curve is slightly different. The same doing the same thing, but the different format. In a sense that that this is for the tsunami, but given the Inundation depths, that the how likely or how much, what is the probability that a certain level of the damage state would be achieved? So the minor damage, moderate damage, major damage, and so on, so on. So if Inundation depths becomes say four metre, then the most likely the collapse would happen. So that's the fragility curve, and we we have a way to convert those two back and forth with some sort of assumption. I believe.

Keith Porter 01:25:09
So it's so a hazard curve is sort of how frequently the ground shakes with some severity, and the the vulnerability or the fragility are given that it shakes that hard. What's the chance that something bad happens, or what is the degree of loss given that that that degree of shaking happens? Is that about right?

Katsuichiro Goda 01:25:28
Correct. And then the well, when once we have the hazard curve, then essentially the vulnerability curve would change the the x axis, for example, just into the the degree of damage or potentially the loss amount. So initially we had a shaking level or Inundation depths on the horizontal axis. That's a hazard curve, but if we convert that through the vulnerability curve or the fatality curve, we now instead of the hazard value, we get the loss value. So that's kind of practical aspect of this function.

Keith Porter 01:26:05
Have Have you talked to insurers in the past about these these products? What have you heard people say about how they might use your research in in practice?

Katsuichiro Goda 01:26:18
I don't know. You're the only one. You know the the closest contact that I have in the insurance issue industry. So,

Keith Porter 01:26:26
well, I mean, I would I would ask our attendees, you know, if if there's anything you took away today that you might actually you might use in professional practice tomorrow, because I think Dr. Goda would probably value knowing the, you know how it this information you know gets out into the insurance world. So you know if you have thoughts about that, please drop them into the Q and A box. In in the last couple of minutes we've got here, Katsu, if if people take away kind of one thought from your from this present presentation today, what do you think that ought to be?

Katsuichiro Goda 01:27:06
Well, from my point, I mean, like my research point of view, I think that the the the I mean, two two potential messages is that the uncertainty is is critical, and we need to communicate well. So I'm not sure if I did well in this presentation. But like you know, we can get the detailed results, but we need to summarise it in the scenario map, etc. So that kind of risk product, but communicating the results is key. But we need to take into account uncertainty as detailed as possible. Otherwise, the the data or the results are not good. The other things I learned through this kind of study is that the you know the the metrics matter. So like it's being well known, you know the financial risk or insurance risk even or the fatality give a very different picture. So which one to mitigate? So risk management strategy has to be tailored for a specific target, and then multi hazard is really important, and then the hazard interaction is important. So I believe there's many things we can do in the future, and then we should promote such kind of research and practice in academia as well as the the profession.

Keith Porter 01:28:26
Thank you so much. Thanks for this presentation. Very interesting, good. It's important, groundbreaking work. Thank you, everybody else, for attending today. Remember that you're going to find the video, the audio, a written transcript, and the speaker's deck by Monday or so at www.iclr.org/workshops. Please remember to join us in five weeks on November the 13th to hear about Quebec's post 2017 and 2019 flood flood relocation policies and how those shaped unequal recovery outcomes in suburban communities. And with that, I will say thanks again to Dr. Goda and thank you to our attendees for coming today, I hope everybody has a great weekend, and see you next time. Bye, everyone.