Structural Reliability
Prof. Baidurya Bhattacharya
Department of Civil Engineering
Indian Institute of Technology, Kharagpur

Lecture –249
Target Reliabilities and General Conclusions (Part - 02)

(Refer Slide Time: 00:27)

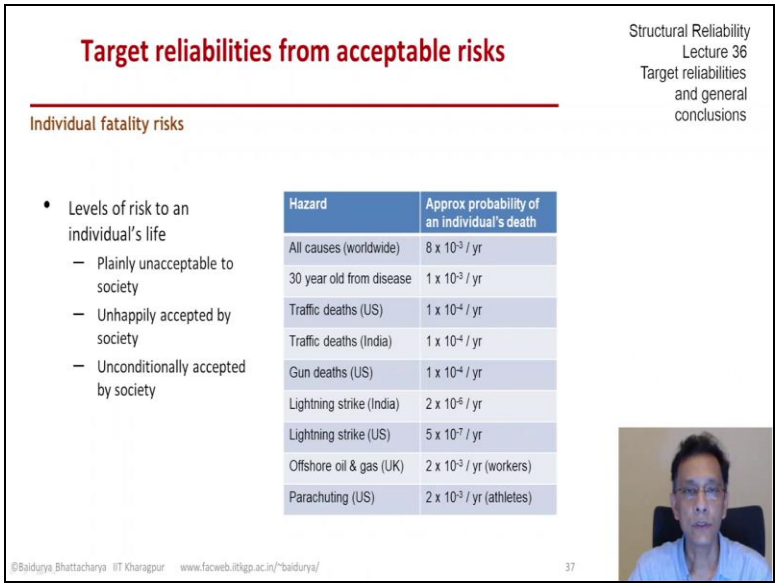
There is a wide range of possible consequences of structural failure. As we have been discussing the loss of life is the most severe and in the next few slides we are going to look at what level of risk to life is acceptable. But there will be many nuances to consider for example if we are able to identify an acceptable risk to life of one individual how we handle a structural failure that involves multiple fatalities.

Then there would also be the question of the context of death was there a choice on the part of the individual individuals by which I mean that was the person a member of the public or was the person professional in charge of say maintaining the building or a construction worker and so on. The other consequences obviously would be economic loss and then what to include in that would be an important question.

And obviously one uncomfortable question that has many implications including moral and

philosophical ones is there a monetary value of human life and if so, how to put that and we also have been talking about environmental damage and if we include that as a consequence how to measure that and this is all in the context of acceptable risk that we have been discussing in the hope of setting target reliabilities. So, let us take a look at acceptable risks to life.

(Refer Slide Time: 02:27)



Let us get some idea of individual fatality risk some numbers but before that the levels of risk to an individual life from society's point of view could be at a level that is plainly unacceptable it could be so, high there are other levels of risk to an individual's life which we may not be very happy about but we grudgingly accept it is kind of intermediate we are ambivalent towards that and then there are on the other end of the spectrum those risks that are unconditionally accepted by society we really don't worry about those.

So, let us take a look at some activities or some hazards and what is the approximate individual life risk. So, a rough estimate of death of an individual from all possible causes worldwide is about 8 in 1000 per year. So, that is a pretty stable estimate across countries. Now if we look at death of a 30 year old individual otherwise healthy from disease that comes to about 10 to the minus 3 per year and which would without a doubt be plainly unacceptable to society.

So, if we have to put an acceptable risk we would need to go well below this then there are other activities which people undertake because of benefits that come from them but the risks are

definitely more than what we would like which example being traffic related debts about 1 in 10 000 per year and that is what we see in the U.S that is what we see in India and we also see a very similar rate of gun deaths in the US.

Now obviously these are not something that society is happy about there are discussions about how to reduce these. So, this level of 10 to the -4 per year per individual would be something that is on the borderline or something that is in the grade between clearly unacceptable and clearly acceptable. Now what would be unconditionally accepted by by society something like death from lightning strike and that is of the order of two in a million per year in India and almost one order less in the US.

So, that is roughly about 5 and 10 to -7 per year now there could be various reasons that the death rate from lightning strikes in India is higher than in the us it is possible there are more lightnings in India it is it is possible that Indians spend more time outdoors on an average in the open or it is also possible that that more people are around in an area where lightning strikes in India than compared to the US.

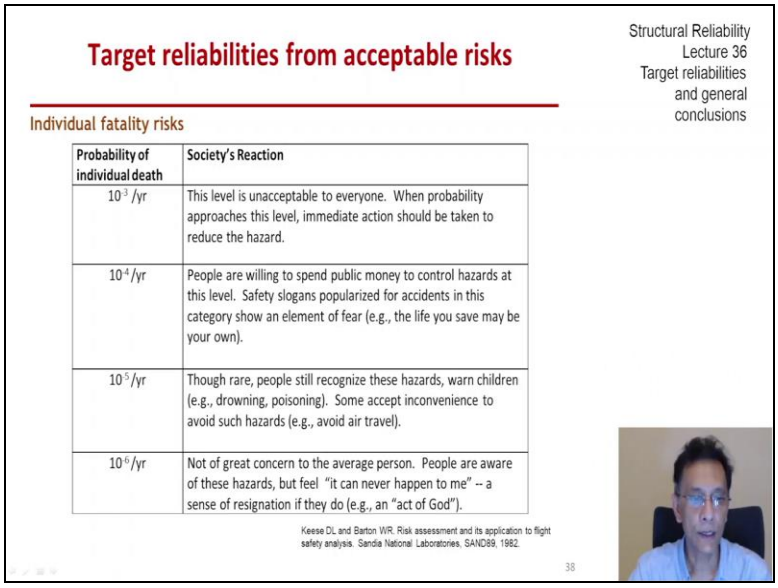
But in any case this rate of one in a million or less would seem to be a number that a society would not be too worried about or would complain. So, we could have this as a basis of what would be an absolutely unconditional acceptance. Now whether this would be too low or not that we can take a look at a little later but there are other numbers that are interesting from offshore oil and gas workers in the UK these are about data from 1960s and 70s that is clearly very high to intend to minus three per year.

On the other extreme also this is from the 70s or 80s that from a very hazardous port which is roughly the same number obviously these are different things these are undertaken in some sense voluntarily. So, there is not. So, much outrage at this level of fatality in these last two mentioned activities compared to what would be that you see in the death from disease that you see in the top.

So, these give an idea about the different ways that society reacts and would also give an

indication of what might be an engineering level of acceptable risk where we to set the target reliability for a structure.

(Refer Slide Time: 08:24)



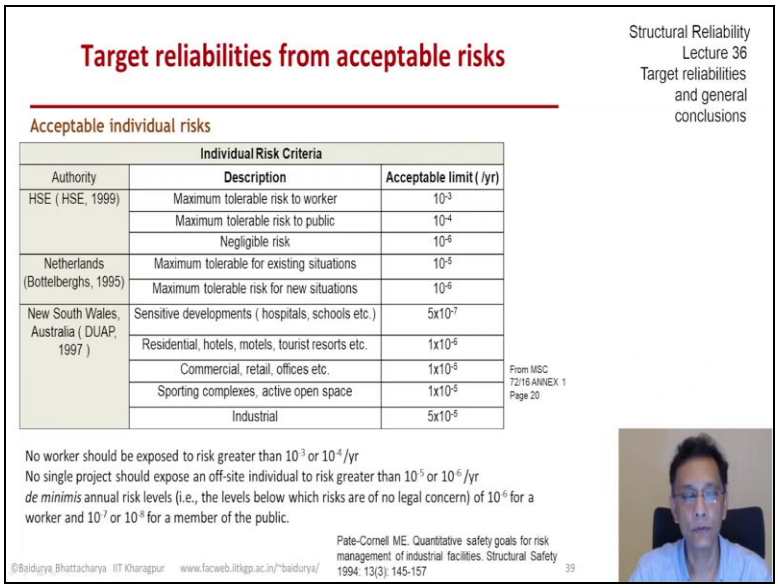
So, in this slide these are this is one this is one set of reactions that society might have given all the different levels of individual risk to life as reported by Keys and Barton's paper. So, as we saw and as we decided that 10 to the -3 per year for an individual is clearly unacceptable and we can see something like this right now in the middle of a pandemic worldwide and clearly the levels of fatality that we are seeing are not acceptable and that is why so, many restrictions are in place and there is so, much concern going on.

Now the next level 10 to the power -4 per year is this is something people are concerned about people are if they if they can be encouraged people are willing to take this up and reduce these risks. So, this would be something that as I said on the borderline of acceptability. The next level is less than the other one that people are still concerned about that but not in a in a significant way and people still warn about these but it is not of great concern typically.

So, if we were to set some targets we would keep this in mind and then lastly the this rate of 10 to the -6 per year for an individual seems to be people are willing to accept and not worry about and sometimes referred to as an act of god and it can never happen to me that sort of feeling. So, with all of these we now see some criteria actually set by some some authorities around the

world.

(Refer Slide Time: 11:15)



So, I have a survey of three countries of the HSC from the UK. So, for a worker the maximum acceptable risk is 10 to the power -3 per year for death for the public it is sent to -4. So, that is on the higher end of the spectrum that we are talking about and negligible risk is one in a million that seems to come again and again from the Netherlands we see a different order of magnitude for for existing situations which people are more comfortable with it's one in 10 to the power 5 and for new situations the tolerable risk is of the order of one in a million.

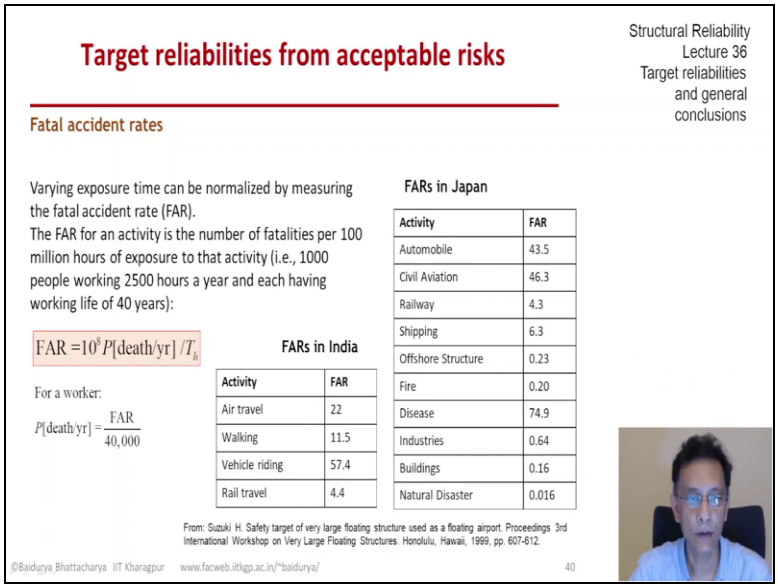
So, that kind of ties in with the negligible risk from the UK in Australia we see some of these numbers and the acceptable rate for schools and hospitals are of the same order of lightning strike in the US. So, they want it to be as low as that for residences they are of the order of 10 to the -6. So, very low which is considered negligible in the UK and for industrial and sporting and commercial activities they are another order of magnitude higher in terms of acceptable risk.

We see something from Patrick Cornell just to summarize the general trend from around the world she came up with certain recommendations that the risk to a worker should not be greater than to the -3 to 1 to -4 per year for a member of the public those would be two orders of magnitude less ten to the -5 to 10 to -6 per year. And the D minimum is that we have been talking that something that is of no legal concern of just no consequence really that is uh that

could be as low as 10 to the -6 for a worker.

And so, that would be the ideal case and for a member of the public 10 to the -7 or even 10 to the -8 per year. So, with these we can try to set see how buildings come in the picture building failures or structural failures and how we could then look at multiple debts. So, these are all for one individual now if there are multiple fatalities possible how we would handle that is also a very relevant question for building or other structural failures.

(Refer Slide Time: 14:30)



Let us also look at this concept of fatal accident rates which is a nice way of bringing in limited exposure. So, what if an individual is exposed for a very limited amount of time and so, what would be the measure of acceptable death from such a limited exposure. So, that is given by the FAR and which is defined as the number of fatalities per 100 million hours of exposure. So, which is the same as 1000 people working full time for 40 years and that is given by this formula.

So, for any activity if T h is which is the exposure time in hours if that is less than 500 hours per year. So, that would be a nice way of putting all these different exposures and risks on the same metric and for a worker one could get back the annual fatality risk as the affair divided by 40 000. Let us take a look at some of these numbers from two countries one is India which I have computed over the last few years.

So, it is interesting to see that rail travel is the safest when exposure is taken into account compared to all the other modes of travel walking is also a bit dangerous and that is partly because a lot of these walking fatalities occur as traffic related accidents. In Japan in comparison we see some different sorts of numbers and we see that it in terms of you know some of these numbers about air travel and about car travel and rail travel the numbers between India and Japan are of the same range.

Especially in terms of rail travel that number for buildings is actually very low which seems to be a very good thing in terms of structural failures. But now we are going to look at what happens for buildings and especially when multiple failed multiple fatalities are involved.