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Analyses of risk from natural hazards for early planning of new highways in Norway

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KJELLER VINDTEKNIKK

Background

- Norway's new state-owned road company 'Nye Veier AS' wanted to establish a method or a process for assessments of natural hazards in the early planning phase of new road projects.
- The aim of the assessments were
  - Hazard identification; Identify critical areas with regards to natural hazards in the planning areas.
  - Risk analyses: Analyse the risk, based on the hazard and the economic consequences of a closed road, combined with consequences for emergency operations.
  - Risk management; Assess potential risk reducing measures
- Analyses were carried out for a total of 700km new roads.

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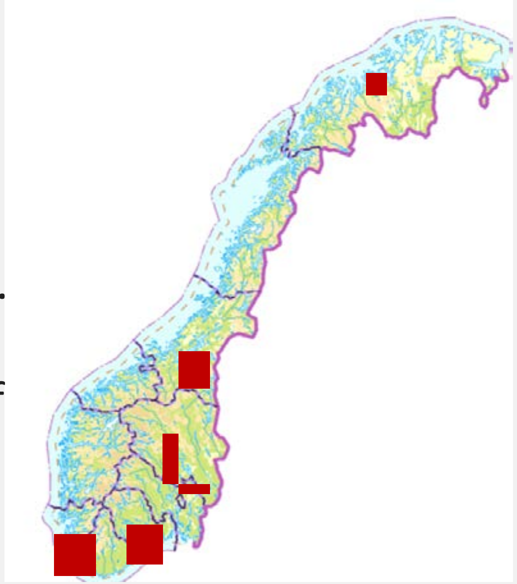
The roads

Located in many parts of Norway, and different climate zones.

Assessing the effects of climate change was part of the project.



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Three project phases

- 1. Development of method
  - Simple analysis along corridors. I.e. within polygons along planned roads.
  - GIS analysis based on existing, publicly available data.
  - Establish a simple tool, which can be operated by the client, in their own premises
- 2. Detailing the method
  - Quantifying risk along a given road stretch:
    - Identify critical objects (e.g. bridges, tunnel entrances, etc.)
    - Assess consequences and risk
    - Assessing climate and climate change
    - Mitigation measures
    - Validate the method in the field; visit hazardous segments identified in the GIS analyses.
- 3. <u>Carry out Risk and Vulnerability analyses for the entire 700km of planned roads</u>
    - Results delivered in interactive map products
    - Support for decision-making with regards to final routing and need for mitigation.

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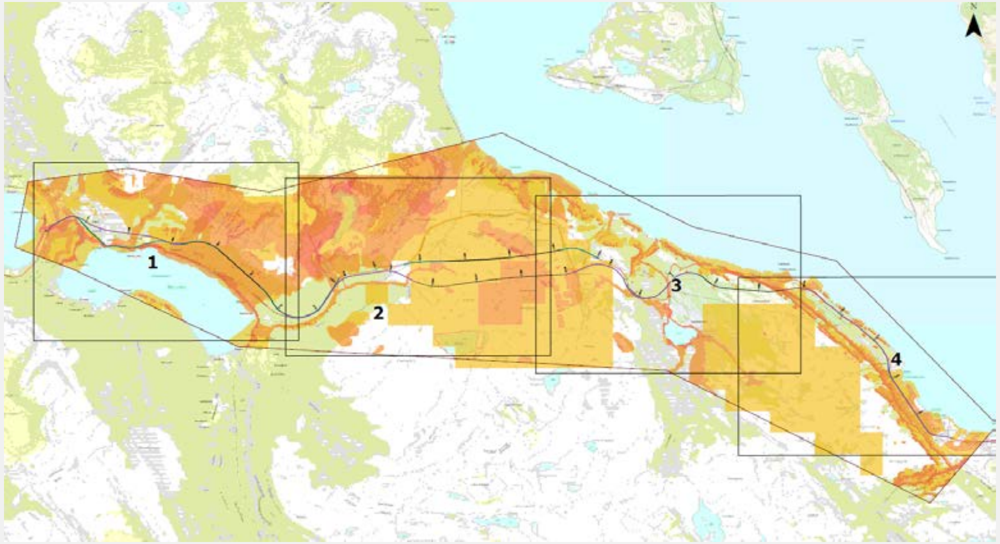
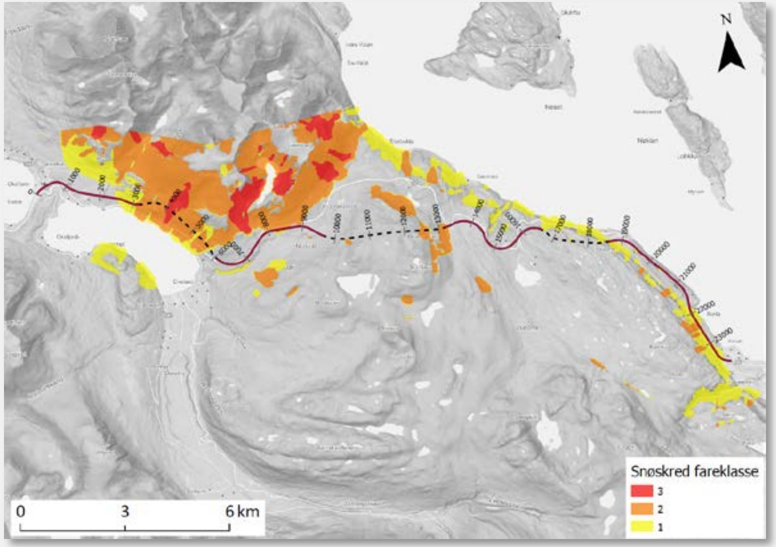
The GIS analysis

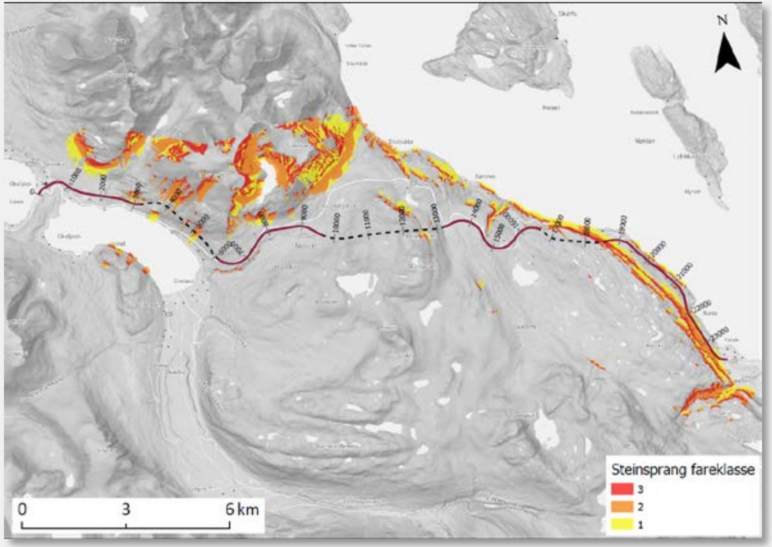


- Hazards to be assessed:
  - Snow avalanches
  - Debris slides / flows
  - Rockfall
  - Quick clay (very sensitive clays)
  - Flooding
  - Wind / snow drift
  - (Storm surge)

- To be analysed along corridors, to provide improved base for final routing and to assess the need for mitigation measures.
- Data from publicly available sources, but optimized using different techniques, as most of the avaiable susceptibility maps are very conservative. Used model tools for e.g. avalanches and rockfall.

The GIS-analysis, examples





Snow avalanches, data background:

- DEM
- Forest data, spatial resolution 25m
- Climate data
- Simulations in 'NAKSIN' (model tool developed at NGI)

Rockfall, data background :

- DEM
- Quaternary geology map, w/ landslide deposits
- Simulations with 'RockyFor3D' (© ecorisQ – www.ecorisq.org)

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3 Hazard levels: Low, medium, high

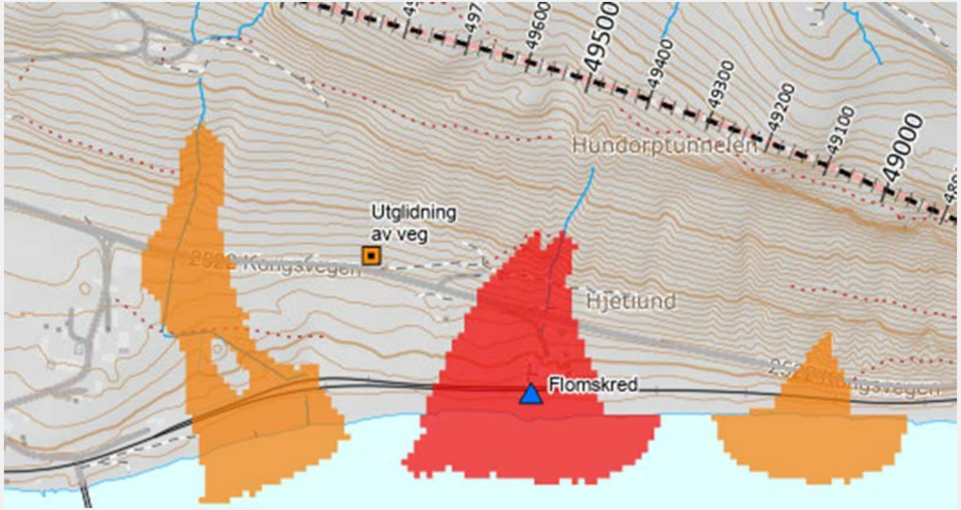
Individual assessment for each hazard type

Ex. Rockfall (Rockyfor 3D):

Haz. level	Definition
3	Reach Probability (RP) > 70 or RP 40-70 and mapped landslide deposits or slope > 44°
2	RP 40-70 or RP < 40 and mapped landslide deposits
1	RP < 40
0	No RP

Ex. Debris flows:

Haz. level	Definition
3	Susceptibility zone and relevant historical event within 50m of the zone.
2	Susceptibility zone and suceptibility class 3 or 4
1	Susceptibility zone and suceptibility class 1 or 2



Probability / return period

Probability class	Description of return period	Nominal probability
5: Very high	More often than every 4. yr	>0.25/yr
4: High	Every 4. – 20. yr	0.25/yr – 0.05/yr
3: Moderate	Every 20. yr – 100. yr	0.05/yr – 0.01/yr
2: Low	Every 100. yr – 500. yr	0.01/yr – 0.002/yr -
1: Very low	More seldom than every 500. yr	<0.002/yr

- These follow Norwegian regulations and are modified for ‘per 1 km road’.

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Simplified field work with Excel based ‘pluck-lists’

Closure (down) time	Recommended measure	Cost of measure (NOK)
1-2 days	Bolts/cleansing/nets	Low: < 100.000
3-4 days	Rockfall fence	Medium: 100.000 - 1 million
5 days - 3 weeks	Channeling	High: > 1 million
3 weeks - 3 months	Sediment nets	
> 3 months	Avalanche fences	
	Erosion control measures	
	Remove / add load	
	Enlarged ditch/Raised embankment	
	Barrier	
	Stream control	
	Culvert / debris flow bridge	
	Bridge	
	Pipe	
	Other measures	

Probability, closure time, measures and costs are assessed in the field and controlled afetrwards.

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Assessing consequences

2 variables:

- Indirect Economic Consequences (IEC)
- Societal security / Emergency preparedness.

Closure time and detour possibilities are key elements for both

IEC

- Costs due to closed road.
- Function of closure time, traffic density and redundancy (detour options).

Societal security

- The possibility for key actors (police, fire brigades, etc.) to deliver their services.
- Affected by:
  - Redundancy (alternative routes)
  - Importance for critical infrastructure (hospitals, airport, defence, etc.)
  - Interconnection between population, critical infrastructre and geographical importance (local, regional, national).

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Assessing consequences

- To the extent possible, differentiate per hazard type along the road.
- Use the most severe consequence class in the risk assessment

	Indirect Economic Consequence	Societal security
5 – Very high	Cost due to closed road > 100 000 001 NOK	Affect key actors' ability to deliver services for > 4 weeks And/or Affect the services in a way which is of national importance
4 - High	Cost due to closed road 60 000 001-100 000 000 NOK	Affect key actors' ability to deliver services for 7 days to 4 weeks And/or Affect the services in a way which is of regional importance
3 - Medium	Cost due to closed road 30 000 001-60 000 000 NOK	Affect key actors' ability to deliver services for 2-7 days And/or Affects the services in a way which is of regional importance
2 - Low	Cost due to closed road 8 000 001-30 000 000 NOK	Affect key actors' ability to deliver services i for <1 day And/or Affect the services in a way which is of local importance
1 - Very low	Cost due to closed road < 8 000 000 NOK	Does not, or to a very small extent, affect key actors' ability to deliver services

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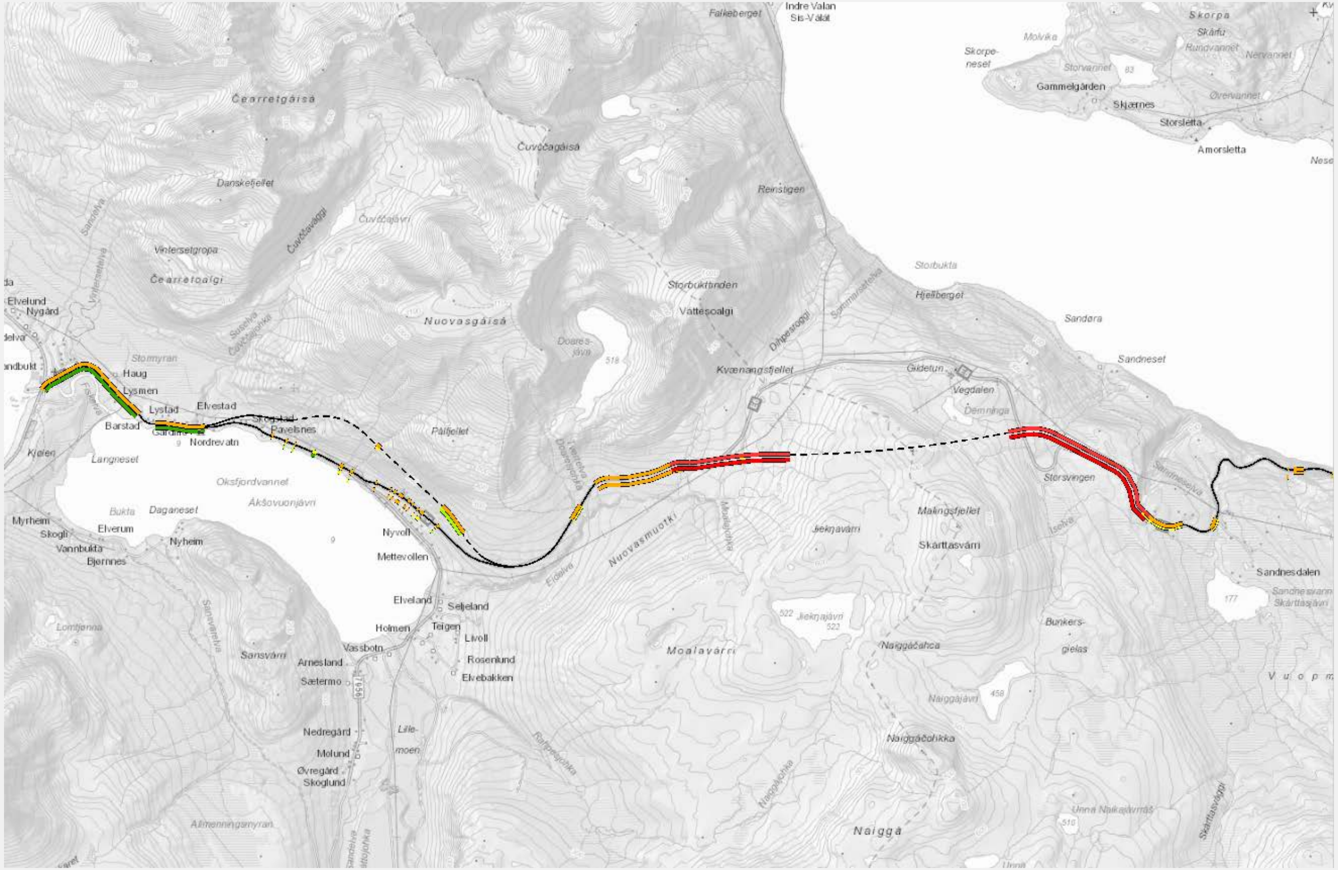
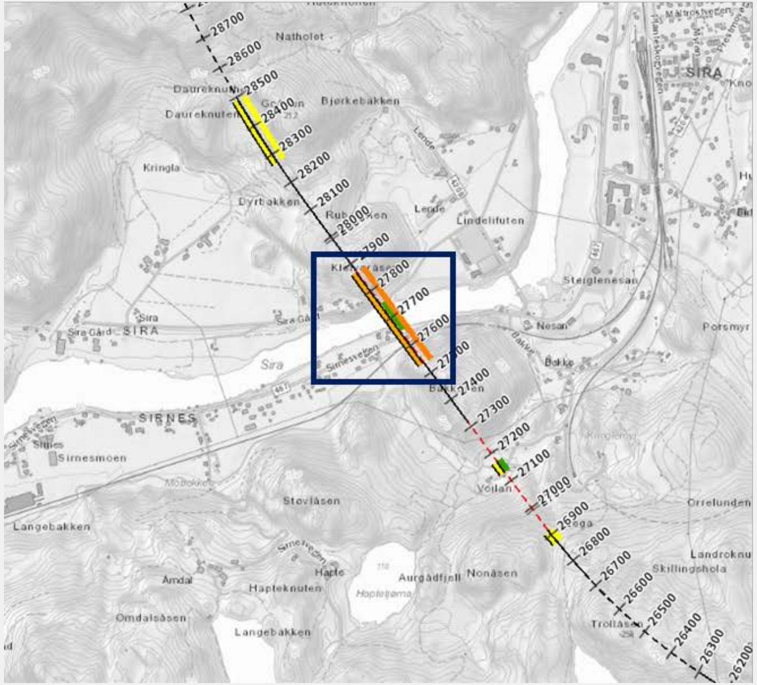
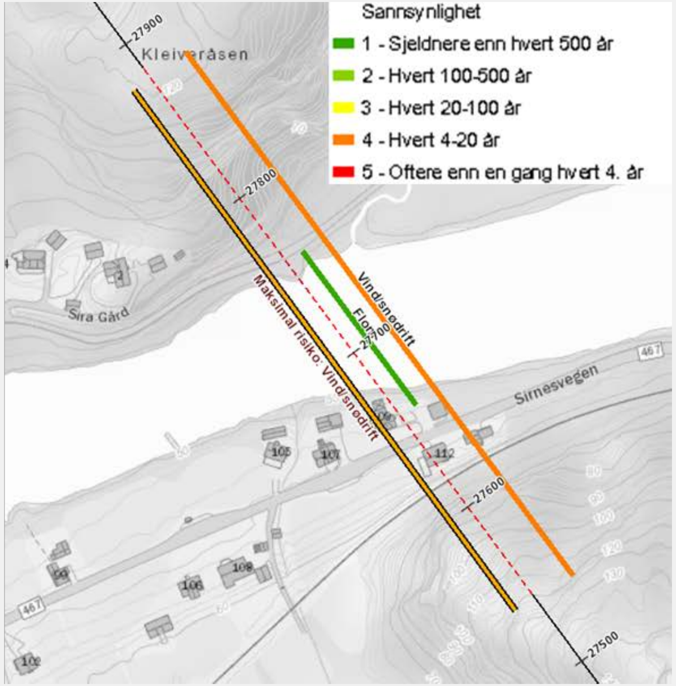
Results: Risk & Vulnerability along the roads



E6 Kvænangsfjellet (northernmost Norway)

Results – Interactive map deliverable





Example shows the crossing of a large river, with potential hazards from flooding ('Flom'; green line) and wind w/ snowdrift ('Vind/snødrift'; orange line). Since the wind hazard has the highest probability, it leads to the highest risk (medium) in this example (brown line).
By clicking one of the hazard lines, a 'fact sheet' with more information appears (next slide)

Fact sheet (one of 795)

- Contains detailed information about the site (sorry for the language!)
- The text explains the probability and the consequences
- Present-day risk is marked with a blue dot in the matrix in the lower right.
- Climate change (precipitation) is assessed, and affects the probability. Risk in year 2100 is marked with a red dot.

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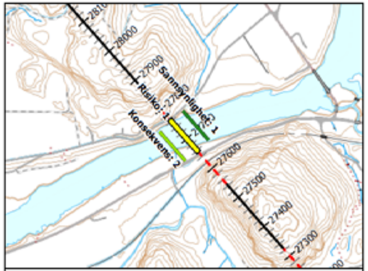
E39 Lyngdal Vest-Ålgård: 27660 - 27760 m

ÅDT (2022): 9900 Lengde: 100 m

Faretype: Flom

Benyttet metrering er uoffisiell, etablert av prosjektet som referanser langs strekningene

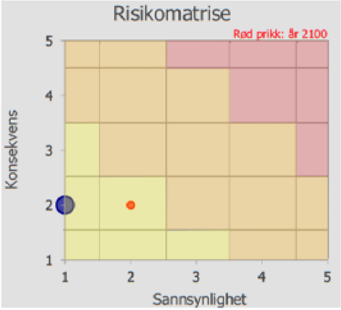
Sannsynlighet:	**1 - Sjeldnere enn hvert 500 år**
Varighet stengning:	5 dager - 3 uker
Mulig tiltak:	Bru
Tiltakskostnad:	Høy: > 1 million
Omkjøring:	Ja
Feltkommentar:	Sira; Stor elv med lav energi. Liten fare for flom dersom trase legges på bru. Sira regulert til kraftproduksjon (Sira Kvina Kraft)
Vurdering IØK:	En hendelse her vil ramme ny E39. Omkjøring blir dermed å ta avkjøring til ny vei og gamle E39 ved Lølandskrysset og følge frem til påkjøring ny E39 ved Moikrysset. Beregnet omkjøringstid er 22 min. Distanse ny E39 er ca. 16 km. Kjøretid 9 min. Antar kø. Hastighet redusert med 50%. Konsekvens IØK: 2
Vurdering beredskap:	En hendelse vil ramme ny E39. Omkjøring blir gamle E39 mellom Birkelandkrysset og Moikrysset. Omkjøring vil kunne benyttes ved uønskede hendelser og konsekvensene av nedetid for samfunnssikkerheten er begrenset. Konsekvens beredskap: 1
Samlet konsekvens:	**2: Hendelsen har indirekte økonomiske kostnader på mellom MNOK 8 og MNOK 30**
Vurdering av klima-påvirkning (år 2100):	**Det anbefales økt sannsynlighet (til hvert 100-500 år) for flom i mindre vassdrag.**



Hendelser:

Risiko på trasé (1-3)

Sannsynlighet og konsekvens på hver sin side (1-5)



NyeVeier

Produsert 19/12/2019 av KST

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Some take-home messages

- The analyses are for the ‘early planning phase’ and are not very detailed.
  - They point out locations where more detailed investigations must be carried out for the detailed design.
  - They are important for planning of the final routing.
- Available national susceptibility maps are conservative, and routines for optimizing the hazard information had to be developed
- A first assessment tool, to be used by the client in future projects had to be simple and available for ‘everyone’ in the organization.
- Both the first assessment tool (the GIS-tool) and the final deliverable (the interactive map with fact sheets) were developed in close cooperation with the client.
- The hazard and consequence assessments were discussed with stakeholders with local knowledge, such as staff from the client’s regional offices, and corrected if necessary.
- Both these deliverables are now installed at the client’s premises, and are being used.
- The client is very pleased with the deliverables, and the communication around the development has been very fruitful for both parties.
- The work has led to cost savings for the client of several hundred million NOKs

Thank you