

**KEM Research review, evaluation and interpretation (max. 4 pages + annex)**

**TITLE Vulnerability of infrastructures and the potential use of sensor information**

**KEM Quality review**

*Description of the scientific quality of the results (team, research method, research results, quality of the products, ...), if needed external review result (project evaluation text website)*

KEM 34 was made of a series of research questions:

- 1) Which infrastructures are most critical for authorities / first responders?
- 2) What are the most probable damage scenarios for infrastructures in Groningen?
- 3) What is the vulnerability of the relevant infrastructures in the area that are necessary for the first period (minutes, hours, days) after a large earthquake has occurred? This includes gas pipes, water, electricity cables and telecommunication.
- 4) How to integrate information about vulnerability of infrastructures to tackle cascading effects in the Groningen system?
- 5) Is it possible to gain relevant information from existing or specifically placed (low cost) sensors on infrastructural objects?
- 6) What kind of information related to the infrastructure is necessary, for whom (e.g. first responders and other operational parties), at what moment (after the event) and in which form?
- 7) How can infrastructures be taken into the HRA toolbox?

It was planned to answer them via three deliverables:

*A) A report on the vulnerability of a selection of the most critical infrastructures in Groningen (a bridge and a sluice are foreseen). The report will include recommendations on how to integrate and communicate the information on vulnerability of infrastructures in the Groningen systems (HRA toolbox) to authorities. Answers questions 2, 3 & 4.*

*B) Sensors installed on the pilot locations with critical infrastructures that are present within the main earthquake region. The sensors should be placed, and readings made publicly available through the KNMI network. The performance of the sensors is to be followed for 1-2 years and a report on the performance has to be delivered after this period. Answers questions 5.*

*C) A study regarding the needs of the stakeholders related to the availability of infrastructures in Groningen and towards the information needed for a rapid and efficient response. The study includes the needs of different stakeholders, the current systems in place and the potential for improving the systems for rapid response information. Answers questions 1, 6 & 7.*

In fact, KEM 34 ended up in being part of a now-ended three years large Europe-commission-funded research project TURNKEY (Towards more Earthquake-resilient Urban Societies through a Multi-sensor-based Information System enabling Earthquake Forecasting, Early Warning and Rapid Response actions).

The project has delivered a series of research product, mostly documented via report-type deliverables and peer-review publications available at <https://earthquake-turnkey.eu/publications-2/> and <https://earthquake-turnkey.eu/deliverables-2/>.

The project considered Groningen as a test-bed (TB6) of the project and planned – for this region - a series of action somewhat compatible with the delivering scheme of KEM 34, namely (A-C) above. At the end of the project a series of deliverable result nominally relevant for Groningen and KEM 34, namely at least:

[D2.3: Report on seismic ground motion and urban infrastructure monitoring systems across TBs](#)

[D4.2: Report on recommendations on fragility functions for buildings and infrastructure components to be used in rapid response context](#)

[D4.3: Report on simplified models for the estimation of seismic functional and systemic losses](#)

Other deliverables can also be considered of interest to the authorities of The Netherlands about infrastructural risk.

The project originally planned to install monitoring systems in three infrastructure components in The Netherlands, but ended up in installing sensors in a bridge and a sluice. This is also documented in a short installation report accompanying the deliverables. No information about the operation of the system is available to this reviewer.

Finally, a manuscript is in preparation regarding the *Seismic fragility functions for embankments on liquefiable soils affected by induced seismicity* (Mario Martinelli et al.), which directly relates to the infrastructural vulnerability in the Groningen region.

The team involved in the TURNKEY project is believed to be very good, with some excellence at the European level, with respect to the questions raised by the KEM 34 research question. It is also undeniable that the TURNKEY project has developed a large amount of knowledge related to its objectives.

On the other hand, it seems that most of the added value of KEM 34 is more in the involvement of the Groningen region and related Netherlands' scientific and governmental network with the European research community of engineering seismology and earthquake engineering, rather than the delivery of operational tools for seismic risk management and/or direct answers to the questions above.

#### **KEM Evaluation of the results**

*Evaluation whether the research questions are addressed adequately (questions answered, precision and uncertainties on outcomes, potential consequences on current practice addressed, ...) (project evaluation text website)*

The TURNKEY deliverables partially contributed to answer to the set of questions posed by KEM 34. In particular, it has:

- 1) provided a global overview of the monitoring system in place in the Groningen area;
- 2) based on standard taxonomy, selected fragility curves for bridges, viaducts and underpasses and buildings (these are from the NAM reports on fragility and consequent modelling);
- 3) installed monitoring instruments of infrastructure components in the region (a viaduct and a sluice) as part of the KNMI monitoring network.
- 4) developed fragility functions for embankments subjected to liquefaction hazard (which replaces deliverable C in the previous section).

As it regards (1), the main value is in a one-place overview of the monitoring systems for the ground and buildings currently in place in the Groningen region.

As it regards (2), the value is in the possible use of the selected curves for the road (transportation) infrastructure risk analysis of the Groningen region.

As it regards (3), the value is to possibly monitor the excitation of these infrastructural components in future events in the region.

As it regards (4), the value is in the possible use of the developed curves for the road (transportation) infrastructure risk analysis of the Groningen region. This reviewer has to note, however, some limitations of the study developing fragility curves for embankments on liquefiable soil, which still have to go under the scrutiny of peer-review to be considered acceptable for risk analysis applications.

In general, the quality of research is considered good, although only partially answering directly to the questions articulating KEM 34.

#### **KEM interpretation of the outcome**

*The interpretation of the results (consequences on methods/data to be used in practice, on risk instrument modules, on inspection procedures and operator procedures, ...) (project evaluation text website)*

The outcome of TURNKEY that are relevant to KEM 34 can help future risk analyses at the regional level of the Groningen region, including some infrastructure or infrastructure component.

In general, the TURNKEY project followed the principle of Performance-Based Earthquake Engineering, and therefore its results are potentially directly used to extend the public hazard and risk analysis of Groningen as implemented by TNO.

Moreover, looking at the deliverables and publication of TURNKEY (<https://earthquake-turnkey.eu/publications-2/>, <https://earthquake-turnkey.eu/deliverables-2/>) other results of the project can be of interest for the Netherlands.

#### **Closure text for the website**

*A summary in simple terms of the goal, the outcome and impact on mining policies or toolboxes of the research project (project evaluation text website)*

KEM 34 was related to the risk, with respect to induced seismicity, of infrastructure in the Groningen region. It was a special situation with respect to other research questions analysed by the KEM panel so far. Indeed, it was not tendered directly to a specific group to address, but it was embedded as a part of a larger research effort, that is a European-commission-funded three-year research project towards enhancing the framework of risk analysis via monitoring systems.

The deliverables of KEM 34 partially delivered comprehensive tools to carry out risk analysis for infrastructure and guidelines to gather vulnerability information from monitoring systems of infrastructural components. Some of these tools also still need consolidation.

Nevertheless, the interaction of The Netherlands with a wide and high-level research community in Europe, with the exposure of the Groningen case as a testbed for the TURNKEY project, is considered significant added value and knowledge investment, such that KEM 34 can be considered successful anyway, in terms of capacity building.