Royal Netherlands
Meteorological Institute
*Ministry of Infrastructure
and Water Management*

Final Report
Market Consultation for the Modernization of the KNMI observation infrastructure

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Colophon

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Content

Introduction

The Royal Netherlands Meteorological Institute (KNMI) is the Dutch national weather service. Primary tasks of KNMI are weather forecasting and monitoring of weather, climate, air quality and seismic activity. KNMI is also the national research and information centre for meteorology, climate, air quality, and seismology.

Large parts of KNMI's meteorological observation infrastructure stem from around the year 2000 and are outdated. In order to sustain its duties regarding delivery of observational data, KNMI intends to modernize the meteorological measurement network in the coming years. This includes all functionality between the meteorological sensors deployed in the field, and the dissemination/delivery of quality-controlled data to end users in different application areas, like climatology, aeronautical meteorology, hydrology. KNMI cooperates with (semi-)governmental partners in these domains to operate the network on a 24/7 operational basis.

As a preparation for the renewal of the observation infrastructure, KNMI gathered information from various sources such as experiences and SWOT analysis of internal users and administrators, developments at other meteorological institutes, and proof of concepts. To gather information about possible market solutions, including a general overview of project costs and total cost of ownership, KNMI decided to issue/organize a market consultation.

In this Final Report we will give an overview of the answers given and the conclusions drawn from this market consultation. We will start with a recapitulation of the purpose, planning and process of the market consultation. Then, the description of the problem domain will be repeated as stated in the original market consultation document. This will be followed by a summary of the responses per question. We will wrap up with some general conclusions and learning points that resulted from this market consultation.

We would like to thank all participants in this market consultation for the effort they have made in answering our questions and, in some cases, in preparing and participating in the explanatory meetings.

1 Market Consultation

1.1 Purpose of this Market Consultation

The purpose of this market consultation is to gather information about possible market solutions, including a general overview of project costs and total cost of ownership, for the modernization of KNMI's observation infrastructure.
The responses to this market consultation are used to improve KNMI's knowledge of possible solutions for (parts of) the problem domain. Also, the responses help KNMI to arrive at an optimal buy or make strategy.

As stated in the original Market Consultation document, KNMI emphasizes that this market consultation is not intended to select partners anticipating on the development and implementation of its new observation infrastructure. Also note that participation in this market consultation will in no way have a positive or negative influence on the option to participate in a tender if KNMI decides to start up a tender process.
Participants cannot derive any rights from this market consultation.

All information participants have submitted is treated confidentially. By submitting a response to this market consultation, the participant has agreed that this market consultation will be used to gather information from the market, to support KNMI in a possible make or buy (in parts or as a whole) decision. In order to maintain the level playing field, if and when KNMI opts for a European tender procedure, in this final report all responses are summarized and processed anonymously. This report is made available to the market consultation participants after the market consultation. It will also be made available to tender participants when KNMI decides to start a tender process. Financial data will not be disclosed.

1.2 Planning

The planning of the market consultation process was as follows:

Activity	Dates
Publication of the Market Consultation Document	21 October 2019
Final date for posing questions	8 November 2019
Publication of the Note of Information	15 November 2019
Delivery of responses by participants	22 November 2019
Inviting selected participants for explanatory meeting	25 - 29 November 2019
Explanatory meetings	2 – 20 December 2019
Market consultation final report	17 January 2020

1.3 Process

All responses to this market consultation have been studied by the KNMI project team. The answers were not scored. Therefore, no value judgment has been given on the answers submitted.

In total, 13 suppliers responded to this market consultation with a (partial) solution for the problem domain, varying from completely proprietary solutions to best of breed COTS solutions or combinations thereof and covering the complete problem domain or parts of it. Three participants were invited to explanatory sessions, to get a more in-depth insight into specific solutions. These participants were selected mainly because they represented a broad overview of the available solutions, not necessarily because these were the best practical solutions.

The market consultation was published on 21 October 2019. A note of information, answering questions posed by participants, was published as scheduled om 15 November 2019. Explanatory meetings were held between 10 and 18 December 2019.

2 Problem Domain

2.1 Introduction

Large parts of the KNMI meteorological observation infrastructure are outdated and a great deal of manual labour is required to keep the observation infrastructure operational. Also, it no longer fits well within the current needs of users and it is difficult to keep up with (inter)national developments. Configuration changes or new sensors and processing algorithms are complex to implement. In the long run, this will lead to operational risks.

Therefore KNMI has initiated a program for the modernization of its meteorological measurement network. The overall goal of the program is to step-by-step grow towards a cost efficient and future proof infrastructure including the linked processes and tools for monitoring, data (quality) management, validation, site inspection and maintenance. The new infrastructure should:

- be flexible in timeliness of data, conversions and interfaces
- support multidimensional data formats
- enable remote access and maintenance and simplify configuration
- be robust and powerful in recovery options
- provide a platform to connect with other data sources
- be based on secure and future proof technology
- all-in-all be the basis for cost efficient data acquisition
- data provenance is to be of the highest quality standards

Sensors used in KNMI's meteorological measurement network range from analogue thermometers to complex sensors like ceilometers and present weather sensors, from which data is ingested locally with a sampling interval between 0.25 and 12 seconds. Measurements are sent from the observing site to a central system where all data is collected, processed and stored.

The total number of sensors is approximately 1,000. Complexity of an observing site ranges from one sensor to roughly 70 sensors deployed at multiple sublocations for the largest international airport. At the airports, the data must be available within seconds after the measurement.

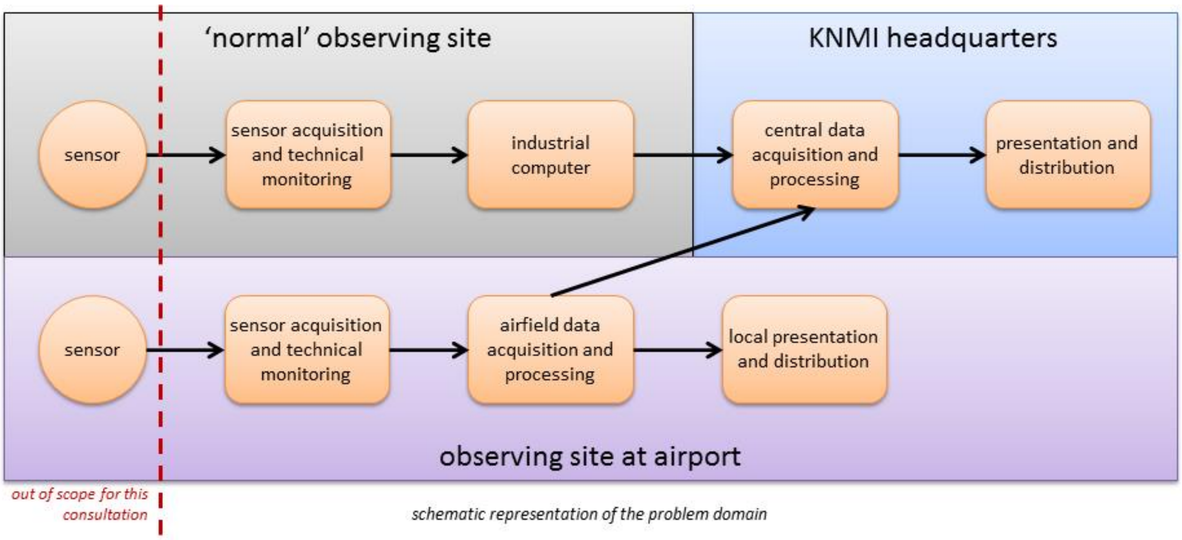
A near real-time graphical display of the measurements is part of the system. The system also creates meteorological reports like (AUTO) METAR, (AUTO) SPECIAL and (AUTO) ACTUAL. Meteorologists can add additional information to these aeronautical reports.

The sensors will not be replaced, so the problem domain is from the local interface with the sensor at location until and including a centrally available storage. Whether or not local presentation and distribution will be part of a possible tender is not decided yet.

KNMI's IT and data infrastructure currently is a mix of legacy and cloud solutions. KNMI's IT Strategy for the coming years is based on a "cloud-first" approach.

2.2 Schematic overview

Observing sites can be divided in basic automatic weather stations, and locations at airports. The same sensors are used and sensor acquisition and technical monitoring are identical. At automatic weather stations, measurements are collected in an industrial computer that serves as a gateway for central data acquisition at KNMI headquarters. At the airports measurements are collected in a computer that primarily serves as the source of information for all observations and reporting needs at the airports. Secondarily it also serves as a gateway for central acquisition.



schematic representation of the problem domain

3 Questions and Answers

In the following section an overview is given of the answers received to each question asked. The answers are summarized and anonymized. The questions are grouped corresponding to the grouping in the market consultation.

3.1 Overview

Question 1

Please provide a general overview of your proposed solution for the modernization of KNMI's observation infrastructure. This may be a solution covering the full problem domain or a partial solution for parts of the functionality described in Section 2.

Summary of Answers
As we stated in our market consultation, we welcomed both complete solutions as solutions for parts of our observation infrastructure. Both types of answers were present. Proposed solutions range from commercial-of-the-shelf solutions to tailor made solutions using open source or commercial building blocks.

Question 2

What are your plans regarding future developments of your solution?

Summary of Answers
Answers to this question varied too much to be able to give a general summary of the answers without breaking the anonymity of the participants. Answers did provide us valuable insights though.

3.2 Functional/Technical Capabilities

Question 3

Situation: On airports, interruption of the flow of observations could lead to costly delays or even cancellation of flights. Therefore reliable and uninterrupted delivery of observations is paramount. How would your solution mitigate the risk of interruptions? What figure would be realistic for the availability throughout the year, assuming sensor and local data communication have 100% availability? What redundancy measures would you recommend?

Summary of Answers
Almost all parties mention redundancy in hardware, communication and power supply as important measures. Answers to this question suggest that 99% availability is certainly realistic, but opinions differ about the number of 9's that can be added. Since we will need over 99% at some locations, this will be an important issue for the realization of our new observation infrastructure.

Question 4

Situation: To align with other KNMI developments and KNMI's IT Strategy, we consider implementing a cloud-based solution a requirement for this project. Do you consider this a sensible requirement? Could you advise us about risks and consequences for cost and reliability? Would differentiation between airports and less time-critical locations be recommendable?

Summary of Answers
No participant advises against a cloud-based solution, although some participants indicate that a (partly) local solution for the critical operations at the airports may be needed (in terms of availability and timeliness of data). Some participants suggest measures to prevent lock-in to one specific cloud provider. Others advised us to keep good track of the various costs of cloud solutions.

Question 5

Situation: We have a variety of instruments with different update intervals (0,25 sec for wind, 12 sec our current default, 15 seconds and 1 minute for present weather sensor), using different communication protocols (RS485, RS422, Modbus, TCP/IP). How does your solution handle this variety of update intervals and communication protocols, and will it accommodate combining results with different intervals? Does your solution work with configurable intervals?

Summary of Answers
According to the answers to this question, participants do not expect serious problems here. Protocols are either supported out-of-the-box or can be added relatively easy. Our current intervals appear not to be demanding in modern IoT environments.

Question 6

Situation: The types of sensor data vary between simple scalars and complex, multidimensional data like wind profiles and droplet size and fall velocity spectra. Also the data formats vary, requiring different methods of processing. What approach would you recommend for the acquisition of sensor data? Would you recommended a different approach for these different measurements? What data format would you recommend and is this an international standard?

Summary of Answers
Most participants do not recommend different approaches depending on the different types of measurements. The possibility to define different ingestion points is mentioned as an option to handle different demands on priority or latency. JSON is mentioned often as data format.

Question 7

Situation: For research purposes, raw sensor data should be acquired from the sensor as well. This information can be bulky, but delivery is not time-critical.

What would be your approach for the acquisition of raw data and near real-time data? What would be your approach for recovery? In addition, would you advise a different approach for recovery of raw and near real-time data after a communication interruption?

Summary of Answers

Many participants advise separate ingestion for raw data to prevent disturbances of the time-critical observations: either a batch-solution or a different 'stream' that will have a lower priority. Some participants believe that the expected amount of data does not require a separate approach for raw data.

Question 8

Situation: The requirements for timeliness of data generated by the measurement network differ. Current observations must be accessible in seconds, observations of the past few days and raw data have less strict requirements on timeliness and for information from previous months or older timeliness is hardly an issue.

What kind of storage strategy would you recommend for this situation? Could a made-to-measure storage strategy deliver significant cost savings? What would be the disadvantages of such a strategy?

Summary of Answers

Many participants believe that a distinction between 'hot' and 'cold' storage can significantly reduce costs. Some participants indicate that a made-to-measure storage strategy comes with costs of enhanced complexity and extra development effort.

Question 9

Situation: Every observation needs metadata, such as the location and time of the measurement, the sensor used and the processing algorithm used. Currently the registration of the whereabouts of every sensor, its firmware and sensor status is located in different systems and not directly linked to the measurements.

What would be your solution to make metadata readily available with the measurements and to prevent human error in this registration as much as possible?

Summary of Answers

Almost all participants suggest that sensors should be able to identify themselves and to present all relevant metadata without human interaction. Some suggestions are made to make older sensors self-identifying. It may be useful to distinguish between dynamic metadata, like the timestamp of the observation, and more stable metadata, like the firmware version and current location of the sensor. Dynamic metadata must be included in every observation, while for stable metadata on-demand information that is somehow linked to the observation is an option.

Question 10

Situation: Currently the interface between sensor and central storage is a small microcomputer, specific for the sensor type, and an industrial PC with local storage at the observation site. How would you design this interface to ensure a reliable delivery of observations?

Summary of Answers
Almost all participants recommend some computing facilities at the Edge, i.c. the measuring location, but a direct connection to computing resources in the cloud is mentioned also. It is mentioned that local hardware and software will introduce extra points of failure.

Question 11

Situation: The micro computers used in our network have on-board algorithms for near real-time quality control and the calculation of derived variables. We intend to extend our near-real-time quality control in the future. Does your solution allow inclusion of KNMI-specific algorithms? Can KNMI independently perform changes to the algorithms?

Summary of Answers
All participants indicate that including KNMI-specific algorithms are possible, in principle, but dependent on their complexity. The ease of adding those algorithms varies. Some solutions provide a separate environment controlled by KNMI that can be deployed while the system is running.

Question 12

Situation: In the future KNMI expects to acquire more observations from third parties (e.g. Water Management Boards and other (semi-)governmental partners) or internal sources into their database. How easily could new sources of observations be included in your solution?

Summary of Answers
None of the proposed solutions appears to have much difficulties with adding extra data sources. Apparently our question was not 100% clear. A limited number of participants answered the question for adding extra sensors. This is important too, but the question was intended for data sources from sensors operated and controlled by other parties.

3.3 Network Management

Question 13

Situation: Currently KNMI does most maintenance, upgrades and troubleshooting of the sensors and sensor interface modules on site. Possibilities for remote access to and remote maintenance are limited to non-existent. KNMI would like to minimize the need to visit locations. Possibilities for remote access and maintenance are paramount in this regard. How does your solution support this ambition?

Summary of answers
All proposed solutions support remote control of local hardware, as far as the local hardware itself supports this. One of the participants warns against possible architectural and service level issues when communication is subcontracted.

Question 14

Situation: Currently KNMI has to put much effort in managing and configuring the system, acceptance testing of new releases and documentation. How is change management included in your solution? Consider for example, the implementation of a new type of sensor.

Summary of answers
There are huge differences between participants in the answers to this question. The most useful ideas in our opinion are: • A modular architecture were the variation between sensor types is confined to small specific modules. • Good version management of configuration and processing logic. • A representative test environment, which supports staging, deployment and rollback of important changes.

Question 15

What is your approach to ensuring data-quality, data-integrity and data-security?

Summary of answers
Measures like using VPN, TLS, certificate based encryption, 2-factor authentication and the encryption of stored data are mentioned. It is also mentioned that authentication and device key management are standard functionalities of all major cloud platforms. One of the participants recommends to store and handle data offline, not in the cloud, when tampering with the data could result into serious accidents. This could apply to airports.

3.4 Costs

Question 16

What are the most important items defining Total Cost of Ownership? How will your solution help KNMI in minimizing those costs? Take into consideration the required effort for managing and configuring the system, possibilities for automated testing and system-wide changes. Please provide an overview of the (estimated) TCO for a period of 5 and 10 years.

Summary of answers

Regarding the items defining TCO, the following items were mentioned most:

- Project costs
  - Project management
  - Hard- and Software development
  - Implementation / Installation
- Costs of Ownership
  - Service and maintenance costs
  - IT services (licenses, network costs, maintenance costs, cloud / on premise / hybrid)
  - Costs of changes

Important cost influencers that were mentioned:

- Vendor independence
- Open systems / open source
- Adaptability / Flexibility with regard to new developments
- Choice of proprietary vs COTS vs Modified of the shelf
- Choice of cloud vs on premise vs hybrid solutions
- Make or buy decisions regarding the whole or parts of the problem domain
- Fully integrated solutions versus combining best of breed solutions
- Automation of manual labour

Regarding the TCO estimates for a range of 5-10 years:
Answers range from an overview of costs or a cost range in some detail, using assumptions for those elements that were not provided by KNMI, to there not being enough information available for making a valid TCO estimate. For those estimates that were provided, we must conclude that they vary quite substantially, depending on the assumptions made. Takeaway for KNMI is that more detail is needed in order to get an accurate and reliable estimate of TCO.

3.5 Project approach

Question 17

Should KNMI decide upon a tender, what should, in your opinion, be the key criteria to decide upon the best proposal?

Summary of answers

The following key criteria were mentioned:

- Regarding vendor(s):
  - Quality of project, implementation and transition plans
  - Experience in similar projects and proven track record
  - Qualifications of staff (in general: Vendor capabilities)
  - When selecting multiple vendors: Experience in working together
  - Capability of delivering support for 10+ years
  - For cloud solutions: Capabilities of cloud provider
  - Experience in long term partnerships with customers
- Regarding project / tender approach:
  - Division of tender into manageable parts
  - An iterative / phased approach
  - Verification meetings / pilots / proof of concept should be part of the tender process
  - Prevent vendor lock-in
  - Proprietary versus COTS or Modified of the shelf
  - Open versus closed source
  - Make or buy decision, depending on knowledge and capabilities of KNMI
- Regarding the quality of the solution:
  - Modularity
  - Compliance with functional and technical specifications
  - Connectivity; ease of integration with other systems
  - Fitting, scalable and maintainable architecture
  - Flexibility
  - Adaptability / agility with regard to future developments (future proof)
  - Robustness
  - Security
  - Scalability
  - Performance
  - Continuity
  - Maintainability
  - Availability
  - Proven technology
  - Innovativity
- Regarding costs:
  - Initial costs versus recurring costs
  - Initial costs versus costs of changes
  - Trade-off between costs and value of the solution (quality over price)
  - Costs of Cloud versus on-premise versus hybrid
  - Minimization of maintenance costs

Question 18

What is the most important information you require from KNMI to be able to deliver the best proposal?

Summary of answers

The following points were mentioned:

- Clear description of the goal of the project, including success/fail criteria
- Description of current situation and future situation
- Complete overview of the infrastructure, including number and location of sensors
- Overview over business strategy regarding the measurement network
- Detailed architecture of the current and future situation
- Detailed functional requirements (see points mentioned in question 16)
- Detailed technical scope of current and future situation including description of systems that need to interface with or be integrated with the solution
- Clear vision of KNMI on break down of work between KNMI and vendor(s)
- Estimated / required planning of the project
- Clear insight in must-haves, should-haves, could-haves, won't-haves
- Give vendor flexibility to offer the best solution

The points mentioned presume a complete up-front knowledge of the end product(s). KNMI prefers a more iterative, agile approach that gives more flexibility to respond to new circumstances.

Question 19

How would you divide the project in manageable modules with regard to architecture, optimal implementation order (with regard to costs and time-to-market) and interdependence of modules?

Summary of answers

The answers to this question vary, depending on the in-house approaches of the respondents. In a number of cases, a pilot is proposed as a good starting and learning point. The project can then be shaped using the pilot as a basis.
Others have a generic project approach with specific phases, some more waterfall like, others more agile.
Some respondents mention specific point of interest: Airport solutions, infrastructure on the observation site, data communication, cloud solutions.

Question 20

Would you consider this project fit for a fixed-price, turn-key project? If not, what project approach would you recommend? What is your advice regarding phasing of the implementation of your solution?

Summary of answers

Most respondents do not see a turn-key project as feasible. Those who do see a turn-key project as possible, include the need for a contingency budget or a split between time and material phases and turn-key phases. Also, for some respondents, the extensive knowledge KNMI itself has about its observation infrastructure points more in the direction of a partnership than a strict vendor-customer division. Some even expect higher costs from a turn-key approach because of the need for very specific and stable requirements.

Question 21

What do you consider to be the most important risks for this project?

Summary of answers

Many of the risks mentioned are counterparts of the success criteria mentioned in the answers to question 17.

Risks related to the vendor:

- Not having a qualified staff
- Not having experience in this type of project
- Not having the required number of staff
- Delays in delivery of ordered equipment
- Vendor lock-in

Risks related to KNMI:

- Delays in decision process about specific proposals will lead to project delays
- Delays because of incomplete preparation of the infrastructure on observation sites
- Lack of focus of the project
- Resistance of staff to the solution, for instance when jobs are threatened or KNMI staff is insufficiently involved in the project
- Insufficient availability of qualified KNMI staff
- Insufficient governance of the project
- Insufficient documentation

Project risks:

- Cloud fees are very dependent on the volume and manner of data consumption and can often be considerably larger than originally estimated.
- Doing too much, too soon
- Too many different parts in the solution can lead to higher TCO
- Complex algorithms
- Scope creep
- Poorly defined testing and acceptance criteria
- Using technology not proven in market

4 Conclusions

4.1 Respondents

The respondents to this market consultation formed a good cross-section of the market, ranging from respondents with specific meteorological knowledge to IT integrators and technology oriented respondents. The solutions provided ranged from specific solutions for a part of the problem domain to completely integrated solutions.
For KNMI a completely integrated COTS solution is an option, but a combination of specific solutions for parts of the problem domain is also acceptable. This has consequences for the governance of the project.

4.2 Functional/Technical capabilities

Cloud solutions in general are considered useful for the problem domain. However, on airport locations latency and availability are key, so on-premise or hybrid solutions also qualify or might even be required for these locations.
KNMI's latency and performance demands are not exceptional compared to current technical possibilities.
Interesting ideas have been offered for a less error-prone solution and for dealing with metadata, traceability of observations and sensor logistics
KNMI algorithms can in all cases be supported; ease of adding of these algorithms could be an important factor in our decision.

4.3 Network management

We can conclude that remote support of local hardware can be accomplished. Also there are quite some different ways in which data-quality, -integrity and security can be accomplished, though the accent in the responses seem to lie more in de field of data security and -integrity, and less in data-quality.
Change management can be accomplished in a number of different ways. Most important for good change management are a modular architecture, good configuration and version management and good testing facilities.

4.4 Costs

It is clear from the answers provided that more information is needed for a reliable TCO estimate. KNMI needs to take this into account when making or requesting TCO estimates. However, we did gain a more complete understanding of the cost drivers.

4.5 Project approach

The variety in answers do not converge to a specific project approach. Some sort of pilot is often mentioned as a good starting point. Most respondents do not recommend a turn-key project.

4.6 General conclusions

Based on the answers given we can conclude that KNMI's demands are not technically challenging. The greatest challenge is provided by our demands for airport locations. It should be noted that the amount of metadata included and the easy of maintenance of the system varies between the suggested solutions.
This market consultation has not provided us with a clear-cut direction for COTS or made-to-measure solutions. In-between solutions (modified-of-the-shelf) are also an option.