Institute of Transport Economics
Norwegian Centre for Transport Research

ENGLISH **Summary**

Quality Assurance of the New Swedish Public Emergency Network, Rakel G2

Report of June 30th 2023

TØI Report 1972/2023 • Authors: Rasmus Bøgh Holmen, Harald Wium Lie, Inge Mossige, Amund Kvalbein, Anders Ågotnes, Espen Sørlie, Guri Natalie Jordbakke, Jostein Tvedt, Lars Juvik, Sunniva Frislid Meyer • Oslo 2023 • 124 pages

In this investigation report, we quality assure the new Swedish "public protection and disaster relief" (PPDR) network project, Rakel Second Generation (Rakel G2). Rakel G2 is planned as a hybrid network, where a state-owned core network is connected to one or more commercial mobile networks through a so-called "multi-operator core network" (MOCN) solution. The new 5G-based network will provide ordinary data services including video in addition to push-to-talk and messages. Key users will include ambulance services, fire services, sea rescue services and the police. Our mandate is to conduct an evaluation of the planned infrastructure project, applying adapted methodologies from the Norwegian quality assurance scheme for large national government investment projects. The quality assurance includes a project cost analysis, uncertainty analyses, quality assurance of the project preparations and analyses of impacts external to the infrastructure.

In many countries, the legacy emergency networks are approaching the last leg of their useful life. Swedish authorities will replace the current network system (Rakel First Generation, Rakel G1) network with a new public protection and disaster relief (PPDR) network, which in the government assignment is referred to as Rakel Second Generation (Rakel G2). While the existing Rakel G1 network builds on Tetra-technology and primarily offers Mission Critical (MC) push-to-talk and messaging, Rakel G2 will provide additional mobile data services including video and internet of things (IoT) services for a broader PPDR service portfolio. New services create new possibilities for usage and collaboration within and between user organizations.

Rakel G2 is planned as a hybrid network for mobile electronic communication, where a dedicated and state-owned network with 5G radio access in the 700 MHz band will provide the core network. The hybrid solution is intended to create flexibility, where commercial and government infrastructure for radio access complement each other in terms of coverage, capacity and robustness. The core network will be connected to one or more commercial mobile communication networks through a so-called multi-operator core network (MOCN) solution. Key users will include ambulance services, fire services, sea rescue services and the police.

The government assignments have been delegated to the Swedish Transport Administration (Trafikverket, TrV), the Swedish Civil Contingencies Agency (Myndigheten för samhällsskydd och beredskap, MSB) and Svenska kraftnät (i.e. the Swedish electricity transmission system operator). According to MSB and TrV, Rakel G2 ultimately concern authorities tasked with ensuring society's safety and security and that citizens have the right conditions to do so (Myndigheten för sammässskydd och beredskap and Trafikverket 2021b). During 2023, decision documents will be delivered to the Swedish government for continued establishment of Rakel G2.

Unlike the Swedish government, the Norwegian government has developed a scheme for quality assurance of large national government investment projects. In this investigation report, the Institute of Transport Economics, Dovre Group and Analysys Mason have been hired to conduct quality assurance of the Rakel G2 project in line with the requirements of the Norwegian quality assurance scheme. This scheme requires quality assurance at two stages. The first stage quality assurance (KS1) is carried out prior to requesting the Government to approve the selection of project concept. The second stage quality assurance (KS2) is carried out prior to asking the Government and the Parliament to approve the project's investment budget.

To the extent earlier investigations on Rakel G2 have been carried out, they have not followed the Norwegian quality assurance process. Furthermore, the Swedish investigation requirements differs from the Norwegian, so the project preparations have to some extent been carried out in another order and with somewhat different priorities than in the Norwegian scheme. Consequently, this quality assurance investigation entails elements recognized as both early stage (KS1) and late stage (KS2) quality assurance in the Norwegian scheme.

Furthermore, Swedish governmental agencies do not face the same investigation requirements as set by the Norwegian scheme, leaving them with a less stringent project preparation process and more flexibility in governance. Still, an important premise for the QA investigation has been to follow the methodologies applied in Norway with some adaptions to the status of the Swedish project preparation. The Swedish project is now approaching parliamentary approvement.

Another central premise for this quality assurance is that the concept choice has already been made. This means that the dedicated public protection and disaster relief (PPDR) network with a MOCN solution and the specified MC services is only evaluated against a reference scenario. In this reference scenario, Rakel G1 is gradually replaced with uncoordinated use of commercial electronic communication services in commercial networks. Other concepts, inter alia concerning different extents of utilization of commercial networks and other requirements to MC services, are not considered.

Moreover, our assignment has been to quality assure the preparations of the project which will realize the new Rakel G2 network. Using methodology from the Norwegian quality assurance scheme for large national government investment projects, we conducted four main analyses, each dedicated a chapter in our investigation report:

- **A project cost analysis**, where we have reviewed and evaluated the project's own base estimate for lifetime project costs, established an updated base estimate, compared this to the internal project estimate and considered funding options

- **Uncertainty analyses**, including a cost uncertainty analysis of the QA-team's updated base estimate for lifetime cost and a quality assurance of the project's own method and process for uncertainty analyses on costs and the time schedule
- **Quality assurance of the project preparations**, including key features such as project frames, management and control basis, and strategies and organization
- **Analyses of impacts external to the infrastructure** project, including analyses on direct user impacts, gross user costs, indirect impacts, tax distortions and distributional impacts. Here, the chosen project concept is compared to a reference scenario, where the existing PPDR Network (Rakel First Generation, Rakel G1) is gradually replaced by commercial mobile services in an uncoordinated way.

Quality Assurance of Project Cost Estimates and Funding Options

Introduction to the Project Cost Analysis and Network Overview

This chapter documents the cost model received from MSB and TrV, and our work to review the model. This chapter also describes our proposed changes to the model based on benchmarking and seven expert interviews. We refer to the original model as the "Nova Model" and our revised model as the "Project Base Estimate" or "PBE", measured in Swedish 2024-krones.

The chapter also contains an overall description of the Rakel G2 mobile network and the elements that are included in the cost analysis. A mobile network consists of several elements as shown in Figure S.1.1, and the cost analysis is structured according to this figure.

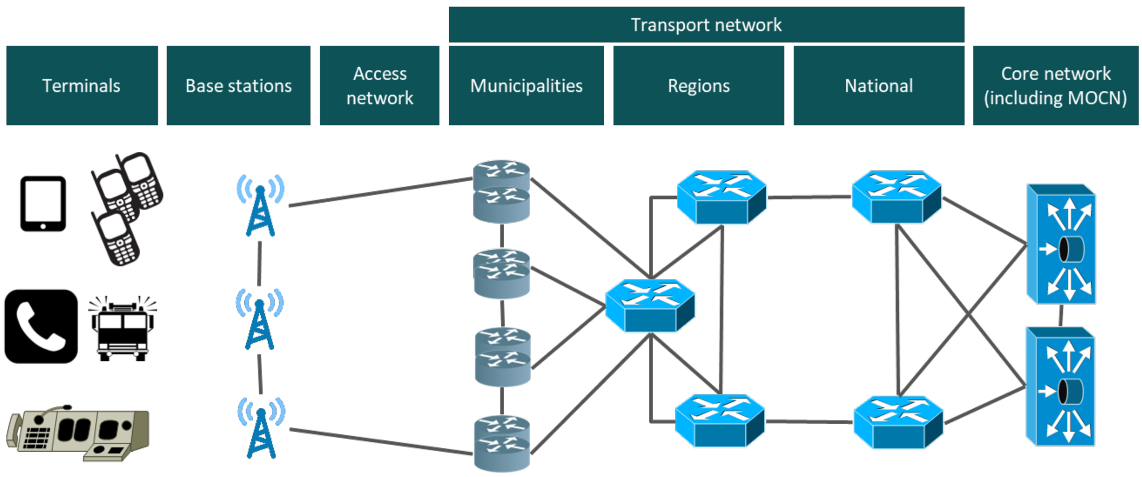

Figure S.1.1: System overview

The figure above shows the system diagram for a dedicated public protection and disaster relief (PPDR) network that we have used as a basis for the cost analysis.

Terminals and Control Rooms

Terminals are shown to the far left in Figure S.1.1. For most end users this means a handheld mobile phone, but it can also mean fixed terminals in vehicles and helicopters or connected sensors and actuators. In addition, there will be equipment in control rooms (such as SOS alarm centrals), where Rakel G2 terminals will be integrated with emergency software applications and public network connectivity. The Rakel organization will specify which types of terminals can be used in the G2 network, but the users are responsible for terminal purchase. Terminal costs are excluded from the cost analysis, while handling of terminals will be an important success factor for Rakel G2.

Base Stations

The terminals communicate with base stations. Rakel G2 plans for more than 7,000 base stations across Sweden, with an aim to provide national radio coverage also in some areas that are not covered by public networks today. The radio coverage will be established using 2x10 MHz of dedicated radio spectrum in the 700 MHz band. The 700 MHz band has good coverage properties with a potentially long range and high penetration of house walls and other obstacles. The data capacity available in this band is, however, limited. The plan is to add extra capacity to Rakel G2 through agreements with one or more commercial mobile network operators.

Access Network

In wired networks, it is common to define the access network as the connection between the end user and the nearest operator node. In mobile networks, we define the access network as the connection between the base station and the nearest aggregation point. Mobile access networks can be built in several ways. In commercial mobile networks, the access network often looks like a star network where one base station has one connection to an aggregation point.

In Rakel G2, the access network will often be built as a ring where each transmitting station has two access network connections. This means that a link failure does not have to mean that the transmitting station loses its connection to the rest of the network. Connections in the access network can be realized in the form of a point-to-point radio connection ("radio link"), a fiber network or even from satellite access. Over time, the proportion of fiber access will probably increase due to new service requirements associated with the new generations of mobile technology. Fiber networks usually have considerably higher capacity than radio links.

Transport Network

Figure S.1.1 shows how the access network connects to the core network sites. In Rakel G2, about 1,200 nodes (“kommun-siter” or municipal sites) will be established to connect the base stations to the transport network. Then, the transport network connects these nodes to central elements such as the core network and service platform.

Core Network and Service Platform

The core network consists of several elements that manage traffic and users. Rakel G2 is planned as a 5G network with a standalone 5G core network. Connected to the 5G core is a service platform responsible for service production. The Rakel G2 will deliver important PPDR services such as voice, group voice and messaging services. In addition, Rakel G2 will provide data services. Mobile data capacity will be increased through access to commercial networks using a multi-operator core network (MOCN) solution where users can connect to the Rakel G2 core network through a commercial radio access network. There are still uncertainties associated with the timeline and scope for the introduction of different services.

Summary of the Project Cost Analysis

The Nova Model is a detailed excel spreadsheet describing new investments, recurring costs, reinvestments and revenues. The model is developed by experts at MSB and TrV. In our analysis, we have restructured this model to achieve a clearer break-down of cost and revenue elements. Figure S.1.2 shows that the Nova Model estimates MSEK 9,100 for initial investments, MSEK 17,900 in recurring costs and MSEK 2,100 for reinvestments over a network lifetime of 17 years. This adds up to a total cost of MSEK 29,100. The Nova Model further estimates revenues of MSEK 16,300, so that the net cost is MSEK 12,800.

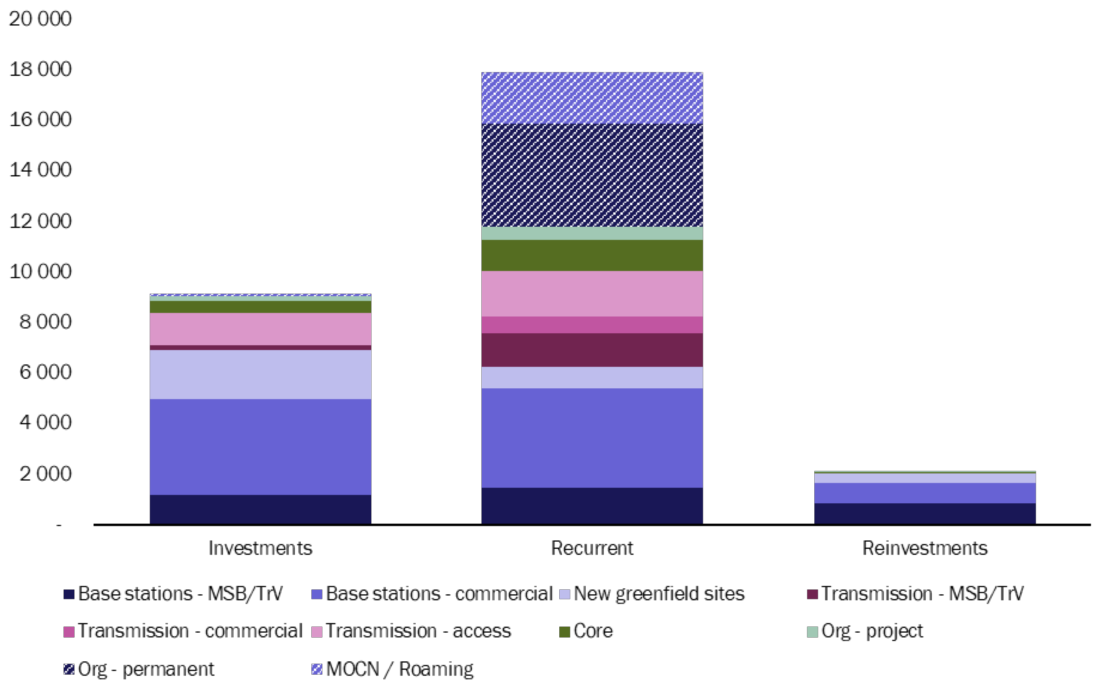

Figure S.1.2: Nova lifetime costs in MSEK

In our opinion, the Nova Model is detailed and thorough. The sources for most estimates have been documented, and cost drivers are explained and modelled in detail. There are, however, important uncertainties that remain and some adjustments that we believe should be made to the model. The most important adjustments are the following:

- Most cost estimates were collected in 2021 and 2022. Since then, inflation in Sweden has been high, and we believe the costs in Swedish 2024-krones will be higher than many of the Nova Model estimates.
- Over time, we assess that energy and construction costs will increase more than other prices. Note that we for energy prices have not included the most extreme price increase in the winter of 2022/2023. These are important cost elements in the Nova Model. We have adjusted the PBE to include an extra annual price increase of one percentage point for construction and two percentage points for energy (not accounting for the extreme energy prices in the winter of 2022/2023).
- The Nova Model does not account for real wage increases for permanent employees. Over time, we expect salaries to increase by 1.15 percentage points higher than inflation.

- On the revenue side, the expected launch of mobile broadband services has been delayed based on input from MSB and TrV. Also, the Nova pricing for mobile broadband is quite a bit higher than what we believe PPDR users[1] will be willing to pay. Therefore, we have reduced expected broadband revenues.
- The Nova Model plans for 143 Rakel G2 employees over time. In addition, there will be 63 additional employees in TrV's transport network divisions to handle Rakel G2. We believe it is possible to run Rakel G2 with 130 employees and have adjusted the PBE to reflect that.

We have also made a few minor adjustments related to model bugs and the cost of transmission equipment. In total, the changes increase the estimated net cost from MSEK 12,800 to MSEK 18,300 as shown in Figure S.1.3 as long as network lifetime is kept at 17 years.

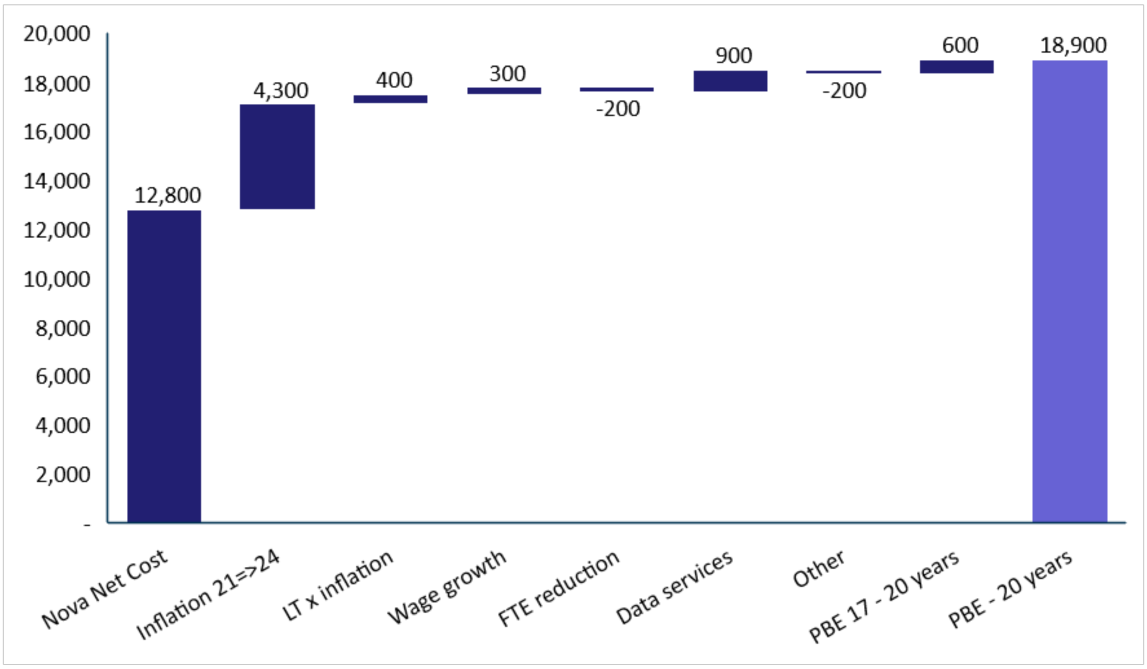

Figure S.1.3: Project Base Estimate in MSEK – changes in net cost

Most mobile networks have a longer lifetime than 17 years, and we believe a network lifetime of 20 years for Rakel G2 is reasonable. This increases the PBE net cost from MSEK 18,300 to MSEK 18,900 ("PBE – 20 years"), but the cost per year decreases from MSEK 1,076 (17 years lifetime) to MSEK 945 (20 years lifetime) as shown in Figure S.1.4 It is possible to extend the network lifetime even further, but this will likely require a higher level of reinvestments.

[1] PPDR: Public Protection and Disaster Relief. In Sweden often referred to as «Blåljus-etater» (directly translated – blue light agencies).

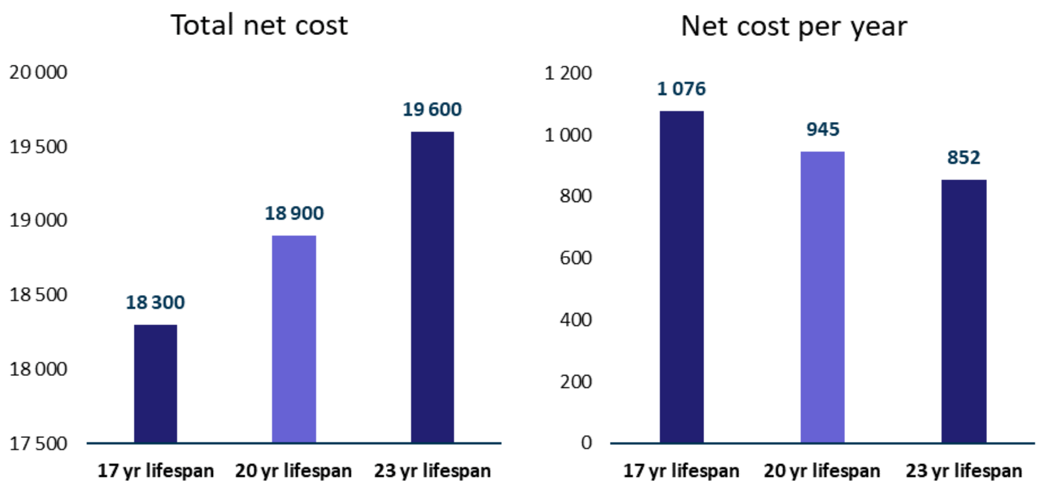

Figure S.1.4: Net project costs in MSEK in a) total (l.h.s.) and b) per year with different network lifetimes (r.h.s.)

We have not made any changes to costs associated with base stations ("sites") and the core network. Site costs are more than 50 percent of total costs in both the Nova Model and the PBE. A detailed radio plan is necessary to estimate the number of sites needed, and the cost per site varies significantly with the types of sites that are deployed. In particular, the cost estimates assume that base stations to a large extent can be placed in existing towers, owned either by Trafikverket or by commercial tower companies. We have discussed the estimates with several experienced Swedish network builders. They all underline the uncertainty associated with site deployment costs, but we are confident that there will to a large extent be space available on commercial towers. This is the most important driver for Nova site costs and we therefore assess that the Nova Model estimate is reasonable.

The situation is different with regard to Core network costs. These costs make up less than 10 percent of total costs, but important uncertainties with regards to functionality and design have made it difficult to assess the cost levels. Uncertainties are related to the complexity of seamlessly integrating the dedicated Nova radio network with commercial radio networks, and the development and timing of the Rakel G2 services. We have not made any changes to Core network costs in the PBE, but underline that these costs are uncertain and that they should be re-assessed at a later stage.

Figure S.1.5 shows the PBE estimated lifetime costs after all adjustments have been taken into account and we use a network lifetime of 20 years. The costs amount to MSEK 10,349, 25,478 and 2,399 for initial investments, recurring costs and reinvestment costs respectively. These are the costs which will be used as the base estimate in the cost uncertainty analysis.

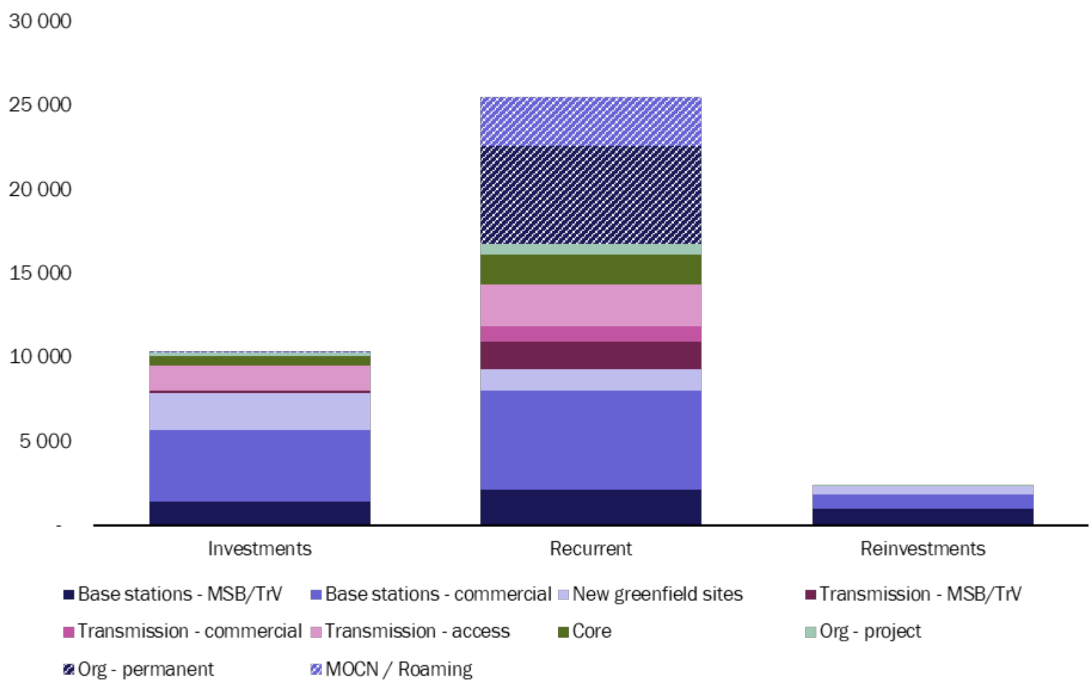

Figure S.1.5: Project Base Estimate in MSEK – Lifetime cost with 20 years lifetime

Summary and Introduction for the Uncertainty Analyses

Introduction to the Uncertainty Analyses

As the Swedish government does not have a fixed scheme for quality assurance of large national government investment projects, the quality assurance (QA) of the Rakel G2 project is based on the requirements for QA of large public projects in Norway, as established by the Norwegian Ministry of Finance. One of the key requirements in such Norwegian QA processes is to undertake an independent uncertainty analysis of the project's investment cost estimate, prior to presentation of the project to the Norwegian government and parliament for investment decision.

This chapter describes the method and analysis results of the independent uncertainty analysis carried out by the QA team of the Rakel G2 base cost estimate, which includes the base investment cost estimate and the base estimate of recurring costs for the operational phase of Rakel G2. These estimates are described in detail in the cost analysis of this investigation. We have also included a brief comparison of methods and results between our uncertainty analysis (UA) of the investment cost estimate and the UA of investment cost established by MSB and TrV in May 2022 (cf. Erdalen 2022).

The uncertainty analysis has mainly been undertaken through a workshop with all key members from the QA group. In the workshop, characteristics of the project have been reviewed relative to their risk potential, and an uncertainty register has been established through brainstorming and review of the uncertainties identified in the UA workshop held by MSB and TrV in May 2022. These uncertainties have been grouped into nine uncertainty drivers. Further, estimate accuracy uncertainties have been reviewed. Three-point estimates, P10 (ten percent probability of being within this cost frame), most likely (ML) and P90 (90 percent probability to be within the cost frame) have been established for each uncertainty element to quantify the uncertainties relative to each base estimate, before Dovre Group's stochastic analytical model (AnRisk) has been used to calculate the results of the uncertainty analysis.

The cost uncertainty analysis is based on an assumption of no delays in project sanction (2024), and no delays in yearly budget approvals. Extreme events (with marginal probability and large consequences), as well as major changes to concept or project premises, are excluded from the analysis. The uncertainty analysis is carried out early in the project preparation phase, with limited documentation available on the project preparations. Hence it is assumed that the project will provide documentation that project preparations are acceptable, with reference to the Norwegian Ministry of Finance's requirements (Finansdepartementet 2019; see also Direktoratet for økonomistyring 2021). The cost uncertainty analysis should be updated and finalized, after the project has completed its documentation on project preparations.

Both the QA team's uncertainty analysis and the MSB and TrV uncertainty analysis are based on the successive method developed by Steen Lichtenberg (2000). However, comparison between the two uncertainty analyses is challenging due to differences in methodology and timing between the analyses. The main difference between the analyses is related to the methodology for the analysis. As opposed to the QA team analysis, the MSB and TrV analysis is not based on a deterministic base estimate, but on an estimate reconciled in a group process.

Based on the results from the uncertainty analysis the QA-team has also made a recommendation on risk reducing measures for each of the defined uncertainty drivers of the project. The most important risk reducing measure at this project planning stage, as assessed by the QA team, is to develop a clearer high-level project design for the Nova project. Such a plan document should describe the services that will be offered in Rakel G2, the time and order in which these services will be introduced, and a realization plan for the services.

The Norwegian quality assurance scheme for major public investments does not entail mandatory requirements for conducting uncertainty analysis of project schedules across time. Yet, uncertainty related to the project implementation over time is most often considerable. An uncertainty analysis of the time schedule for Rakel G2 was also carried out by MSB and TrV and documented in a project internal investigation report by MSB and TrV (Erdalen et al. 2022).

At the end of our review of uncertainty aspects, we have included an analysis of the method and process for this schedule uncertainty analysis, a comparison with the method and process used by Dovre, member of the QA group, and our recommendations for MSB and TrV's next schedule uncertainty analysis (Erdalen et al. 2022). Lastly, we provide a brief comparison of the schedule in the Rakel G2 Planning and Preparation Report (by Myndigheten för samhällsskydd och beredskap and Trafikverket 2021b, made public March 2023) and the results of MSB and TrV's 2022 schedule uncertainty analysis.

Main Results from the Uncertainty Analyses

The main results of the preliminary cost uncertainty analysis are shown in Table S.1.1. Values are given as MSEK with cost level 2024. Recurring costs (i.e., costs related to operations) are limited to 20 years' duration. Reinvestments exclude investment in significant technology improvements and new technology. Recall that terminals and other user costs are not included in the PBE nor in the analysis, as it concerns users and not the infrastructure costs.

*Table S.1.1: Uncertainty analysis results – preliminary. * Not comparable with sum of investments, recurring costs and reinvestments due to portfolio effects*

Parameter	Investments (MSEK)	Recurring costs (MSEK)	Reinvestments (MSEK)	Total (MSEK)
Base estimate	10,349	25,478	2,399	38,225
Contingency	1,467	242	143	1,853
Expected cost (P50)	11,816	25,720	2,542	40,078
Management reserve	2,502	3,467	1,110	4,440*
P85	14,318	29,187	3,652	44,518*
Relative contingency (%)	14%	1%	6%	5%
Relative standard deviation (%)	20%	13%	42%	11%

The uncertainty for (initial) **investment costs** is dominated by market uncertainty, site and transmission conditions and estimate accuracy uncertainty related to unit costs for equipment. The contingency of 14 percent to the PBE (for investments) and standard deviation of 20 percent of the expected cost are within the normal range for a project at this development stage.

The uncertainty for **recurring costs** is dominated by uncertainty related to the operating organization's capability for successfully undertaking the operation and supervision of the network, by estimate accuracy uncertainty related to the number of personnel needed for the operating organization, and by estimate accuracy related to unit costs for the operation scope, that is annual OPEX costs (operating expenditure, i.e., recurring cost for the operational phase). The overall contingency of 1 percent to the PBE (for recurring costs) indicates the base estimate is on a probable level. The QA group has identified the cost estimate for recurring costs based on documented and plausible reference data with low uncertainty. Further, most of the uncertainty elements are assessed with symmetric uncertainty spans. The aggregated uncertainty range represented by one standard deviation of 13 percent of the expected cost is somewhat low, but this must be seen in relation to the quality of the reference data.

The uncertainty for **reinvestment costs** is dominated by estimate accuracy uncertainty related to the percentage used to calculate reinvestment needs, by market uncertainty and by site and transmission conditions. The overall contingency of 6 percent to the PBE (for reinvestments) is low. Yet, it is mainly caused by reinvestments being far in the future, leading to many of the uncertainty elements being symmetrically quantified. The low contingency should also be seen in context with the very wide uncertainty span from the analysis, represented by one standard deviation of 42 percent of the expected cost. This is due to the fact that several uncertainty drivers are quantified with wide uncertainty spans, including the above-mentioned estimate accuracy uncertainty related to reinvestment needs.

Recurring costs amount to approximately two-thirds of the total costs, both in terms of PBE and in terms of expected costs. Accordingly, the analysis results for recurring costs have a profound impact on the overall contingency and relative standard deviation for the total project costs. The overall uncertainty in the project is dominated by uncertainty related to the organization and management, dominant for both the investment phase, the operation phase and for reinvestments. Further, the cost uncertainty is highly affected by market uncertainty and by estimate accuracy uncertainties for recurring costs.

We do not conduct an uncertainty analysis of the time schedule anchored in the project cost analysis, as we deem the affiliated documentation insufficient in our quality assurance of the

Institute of Transport Economics, Gaustadalléen 21, N-0349 Oslo, Norway, E-mail: toi@toi.no www.toi.no

project preparations. For the same reasons, we have not performed a quality assurance of the project's plans and durations, as no current sufficiently detailed schedule exists. Furthermore, the existing schedules from MSB and TrV's project report for planning and preparation of the further development and establishment of Rakel G2 (Myndigheten för samhällsskydd och beredskap and Trafikverket 2021) was compared to the project internal uncertainty investigation in Erdalen et al. (2022). Both have been prepared in an early planning phase. Besides, both are at a very general level with a very limited number of activities, and where the logic and durations of the two existing schedules differ considerably.

Instead, we have carried out a comparative analysis of the method and process of MSB and TrV's schedule uncertainty analysis (Erdalen et al. 2022). As the analysis was done in the early planning phase, few strategies and details were in place. Except for general uncertainties, the study contains no documentation data used nor any description of the reasoning behind durations and uncertainty quantifications. Furthermore, the impact of general uncertainties is only shown for the total project duration and not allocated to the relevant activities and cost their effects. Thus, there is a high likelihood for overlaps in quantifications of activity uncertainties and quantification of general uncertainties. By the same token, MSB and TrV's project internal report breaks down the project into seven high level activities only, leaving subactivities and their dependencies undefined and untreated. In addition, limited identification of a network of processes and dependencies, long activity durations could give a wrong analysis result (ibid.).

Based on our concerns and our impression of changed planning assumptions since May 2022 (when MSB and TrV's internal uncertainty investigation was carried out), we support the Nova project's plans for a new uncertainty analysis on the time schedule in the second half of 2023. Our recommendations for a next schedule uncertainty analysis chiefly concern prerequisites, planning and execution of the analysis and execution plan finalization.

With regard to prerequisites, we recommend the establishment of a high-level project design with an affiliated execution strategy and a detailed draft execution schedule. On planning, preparations and execution, we recommend establishment of a more detailed planning network for the uncertainty analysis, quantification of general uncertainties before estimate accuracy uncertainties, quantification of the uncertainty drivers on activity level rather than overall project level, and documentation of all experience data applied by the workshop participants. In finalization of the execution schedule, we recommend that the project considers how the results from the uncertainty analysis and likely effects of risk reducing measures may warrant changes to the detailed execution plan and that a concise management plan should be prepared.

Quality Assurance of Project Preparations

Introduction to Quality Assurance of Project Preparations

In the 1980s and the 1990s, Norway experienced significant cost overruns on several large public projects. Consequently, from the year 2000 onwards the Ministry of Finance introduced mandatory governance arrangements for major government funded public projects, including requirements for independent external quality assurance of the project management documentation (project preparations) and the project's cost estimate (KS2). Dovre Group has held frame agreements with the Ministry of Finance since the year 2000 for quality assurance assignments, from 2005 in a consortium with TØI, up to today. Since the year 2000, Dovre and TØI have undertaken quality assurance of project preparations and cost estimates for close to 80 projects. The Ministry's associated quality assurance requirements and guidelines have later been revised and further elaborated (Finansdepartementet 2008, 2019a, 2019b and 2020 and Direktoratet for økonomistyring 2021). Quality assurance of project preparations is not needed for parliamentary approval in Sweden, but we still consider quality assurance of the project preparations as highly advantageous also in a Swedish context, in order to reduce risks for cost overruns and project delays.

The quality assurance of project preparations investigates the project documentation within three main topics – the project's overall framework, project strategy and project control basis. Each of the main topics includes four to six subtopics, such as the project's identification of its critical success factors, interfaces, strategy descriptions, project ownership and project execution organization, quality of the cost estimate and of the project schedule. The Norwegian requirements for project preparations are in accordance with sound project practice, and similar requirements can be found in many large international corporations which regularly implement large investment projects, such as energy projects. Furthermore, the consistency between the topics is also reviewed in the quality assurance process, such as consistency between the work break-down structure (WBS), estimate, project time schedule and organization structure.

In the Norwegian quality assurance scheme for major public investments, for projects where the managing documents are found insufficient and the project is deemed immature, the quality assurer will call for more documentation before national government and parliamentary approval. Such a requirement does not exist in Sweden, but to minimize the risk of budget overruns and ensure predictability of the project, it is still recommendable to have thoroughly processed documents for project organization and governance setup.

Summary and Recommendation on Documentation Needs Concerning Project Preparations

Overall, our review of decision preparation documents on project organization and implementation shows a considerable amount of missing documentation. This holds for all key aspects of the affiliated documentation, including the project's overall framework, strategy project and control basis. Moreover, none of the topics assessed in the Norwegian quality assurance scheme for large national government investments were considered having complete documentation, as depicted in Table S.1.2.

For the overall framework, the documentation on purpose, requirements and main concept, and critical success factors, would have met the minimum requirement for quality assurance by the Norwegian quality assurance scheme, despite some weaknesses. The documentation for the other topics would have been considered insufficient to move forward for parliamentary approval in Norway, either due to decisive deficiencies in the documentation (i.e., project framework and project objectives) or non-existing documentation (i.e., interfaces).

For the project strategy, none of the topics met the documentation requirements set by the QA team. The documentation was deemed to involve decisive deficiencies for the execution strategy and the organization and management, while no documentation was found for the strategies on risk management and contract design.

For the project control basis, work breakdown structure and cost estimate, as well as budget and phasing, there was sufficient documentation to move forward in the Norwegian quality assurance scheme, despite some weaknesses. Yet, other documentation would have been deemed insufficient by the Norwegian scheme due to decisive deficiencies (i.e., project schedule and scope of work, including management of change) and non-existing documentation (i.e., benefits realization plan and quality assurance and control).

Table S.1.2: Assessment of missing project preparations – overall framework. Green color: Sufficient documentation. Yellow color: Documentation with some weaknesses. Orange/red color: Documentation with decisive deficiencies. Dark red color: No documentation

Main topic	Subtopic	Missing descriptions / documents	Status
Overall framework	Purpose, requirements and main concept	Purpose described in Government assignment. Precise descriptions of concept, requirements and expected performance missing	
	Project objectives	Objectives included in UA document neither complete, measurable nor prioritized	
	Critical success factors	Not specifically described, but several measures included in UA report can be regarded as success factors	
	Project framework	Descriptions on TrV / MSB's project planning / execution framework, as well as laws and regulations missing	
	Interfaces	No descriptions (technical, organizational, commercial interfaces)	
Project strategy	Risk management strategy	Not described in documents received to date	
	Execution strategy	Brief description only in the Rakel G2 Planning and Preparation Report (Myndigheten för samhällsskydd och beredskap and Trafikverket 2021)	
	Contracts strategy	Not described in documents received to date	
	Organization and management	Division of roles/duties between MSB and TrV is described. Other information on how project is organized and managed is missing	
Project control basis	Scope of work, including management of change	Detailed descriptions of project scope are missing, but quantities are given in the project's cost estimate. No information on change management.	
	Work breakdown structure	Described in UA report from May 2022, but need information/confirmation on final structure	
	Cost estimate, budget and phasing	Detailed estimate received, but overview and verifiability are challenging. Investment estimate not structured in accordance with WBS.	
	Benefits realization plan	Not yet received	
	Project schedule	Brief description only in project's final report	
	Quality assurance and control	Overview of QA/QC procedures and requirements for the project not yet received.	

The quality assurance group was asked to do the quality assurance of the project preparations on project management, governance and organization at a point in time when the project preparations still were not complete. Before the project launch, we strongly recommend that the MSB and TrV prioritize to improve the project preparations and its documentation on project preparations, similar to the Norwegian requirements. We also encourage quality assurance of these documents. However, we acknowledge that the requirements for quality assurance set by the Norwegian quality assurance scheme for large national government investments do not apply to Sweden. Accordingly, the project may have more flexibility with regard to documentation than major Norwegian investment projects.

Analyses of Impacts External to the Infrastructure Project

Introduction and Motivation for Investigation of Impacts External to the Infrastructure Project

In this chapter, we analyze impacts of Rakel G2 that are external to the Nova project. These impacts are in some way assessed at the first stage of the Norwegian quality assurance system (KS1). In addition, except for the user cost analysis, we evaluate the impacts of Rakel G2 against a reference scenario, where Rakel G1 is gradually phased out and replaced by uncoordinated use of mobile network services for public protection and disaster relief (PPDR) purposes. The five impact analyses carried out in this chapter are listed in the following:

- **Direct user impacts**: When focusing solely on the cost side of infrastructure projects, there will always be a danger that one disregards the user benefits, which constitute the motivation for the project solution in the first place. Here, we will explore the user benefits applying a multi-criteria analysis for various stakeholders, reflecting direct beneficial effects of the quality of the mobile network.
- **Gross user costs:** While infrastructure project analysis typically constitutes the core of the appraisal in public infrastructure investment projects, user costs are often ignored, even though they may be substantial. We estimate the gross user costs associated with the whole system integration project, where the term “gross” reflects that the alternative user costs have not been assessed.
- **Indirect impact:** Much of the attention in public debate on public emergency networks is directed towards indirect impacts, which are typically non-monetized. In our investigation, we provide a qualitive overview of indirect impacts, including impacts on aspects of spectrum utilization, cooperation, production economy, knowledge generation, security and environmental issues.
- **Marginal costs of public funds:** In both Norwegian and Swedish methodology for cost-benefit analysis from a society point of view, marginal costs of public funds usually constitute a considerable component of the total net and gross costs. In this investigation, we estimate the net marginal costs of public funds of infrastructure cost and the gross marginal costs of public funds of user costs, as well as assessing tax distortions originating from non-monetized impacts qualitatively.
- **Distributional considerations:** Public decision-makers should not and do not only care about the net benefit of a project, but also about distributional aspects. Towards the end of the project, we have assessed the distribution impacts of the infrastructure project, concerning various stakeholders (i.e., the horizontal dimension), groups with various socio-economic backgrounds (i.e., the vertical dimension), various geographical locations (i.e., the spatial dimension) and across time (i.e., the intergenerational dimension).

Summary of the Analyses of Impacts External to the Infrastructure Project

Public safety users need modern communication services that are reliable, secure and easy to use wherever they operate and in all situations. Based on interviews with several Rakel users, we assess that robustness is the most important user priority, followed by functionality, user experience and coverage. Interoperability and security are also important, while capacity was rated least important.

We have compared the current Rakel G2 setup with a reference scenario, where Rakel G1 is kept alive as long as possible and mobile data to PPDR users is delivered over regular comercial networks.

As the ultimate benefits of increased service quality caused by Rakel G2 are hard to address accurately, we proxy these impacts by addressing direct user benefits for the emergency services. Table S.1.3 shows a relative comparison of the project's assessment of expected user benefits in the Rakel G2 scenario and the reference scenario. Interoperability is the attribute with the highest expected improvement from the reference scenario to Rakel G2. Also, we expect improvements in robustness, user experience, coverage, security and capacity with Rakel G2 compared to the reference scenario. In terms of capacity, it is important to note that it will likely be possible to get priority in commercial mobile networks, which is an advantage with Rakel G2. The anticipated improvements in robustness and capacity both require a seamless multi-operator core network (MOCN) solution. The only attribute where we do not expect an improvement compared to the reference scenario is functionality.

Table S.1.3: User benefits in Rakel G2 versus reference scenario

Benefit	Weight	Rakel G2 scenario
Robustness	23	+
Functionality	21	0
User experience	20	+
Coverage	20	+
Interoperability	18	++
Security	17	+
Capacity	14	+

In addition to subscription fees, Rakel G2 users will incur other direct costs. First, they will have to pay for terminals and in some cases the installation of terminals. In addition, there will be costs for integrating Rakel G2 services with the users' applications and IT systems. We estimate initial terminal and integration costs to be around BSEK 1. This estimate does not include VAT, procurement or training costs. Annual costs are around MSEK 125 per year or BSEK 2.5 over a 20- year span. This means that total estimated user costs are BSEK 3. when both initial and recurring costs are included. Please note that these are the gross user costs of Rakel G2. The net user costs excluding the subscription fees will be lower, as there will be user costs in the reference scenario as well.

Nevertheless, the network subscription costs will most likely be higher than the additional subscription costs associated with Rakel G1 and private subscriptions in the reference scenario. Thus, we expect considerable net user costs associated with subscription fees, which should have been subtracted from the subscription revenues for the infrastructure project in a cost-benefit analysis.

Furthermore, implementation of Rakel G2 induces a wide range of indirect impacts. A brief overview is provided in Table S.1.4.

Table S.1.4: Overview of Indirect impacts

Indirect Impact Group	Description
Impacts on spectrum utilization	• Reduced spectrum availability for public mobile networks • Improved coverage in rural areas • Indirect spectrum impacts caused by competition impacts
Cooperation	• Interagency cooperation between the emergency services • Cooperation with others across networks
Economic	• Potential comparative advantage for Telia from the MOCN solution • Important assignment for the chosen system supplier • Available capacity and healthy competition prevent distortions within construction
Knowledge generation	• Learning outcomes on integration between civil and PPDR networks • Technology-specific training costs and learning outcomes
Security	• National security, network ownership and protection against hacking • Emergency preparedness for the civil emergency agencies and the military • Personal security and privacy • Perceived security
Environmental	• Construction affects landscape value at sites • Daily operations indirectly involve climate through the energy consumption

First, the spectrum utilization is affected by fewer frequencies available for auctions, additional construction of mobile coverage in rural areas and indirect influences through competition impacts. Second, Rakel G2 will affect cooperation between the emergency services and their interaction with other partners applying another network. Third, Rakel G2 will affect competetion and economic capacity in several markets, providing Telia and possibly systems suppliers (e.g., Ericsson) with competitive advantages in the market for telecommunication services and manufacturing, respectively. Competition in the market for telecommunication construction is on the other hand likely to be less affected due to available capacity and healthy competition.

Fourth, Rakel G2 will generate new knowledge on integration between civil and PPDR networks, as well as on technology-specific training costs and learning outcomes. Fifth, Rakel G2 will influence PPDR security, mostly in terms of improvements such as network ownership and protection against hacking, and emergency preparedness for the civil emergency agencies. In addition, the network may enhance personal security and privacy, and contribute to higher perceived security. Last, the project will also entail some environmental impacts such as effects on landscape values at sites in connection with construction and greenhouse gas emissions through energy consumption related to daily operation.

As realization of Rakel G2 calls for tax funding and comes at the expense of tax cuts and welfare arrangements, it will involve distortion in the tax system. We estimate the net marginal costs of public funds for the infrastructure project to BSEK 3.84. Furthermore, we estimate the gross marginal costs of public funds related to the user costs to BSEK 1.05, where user costs in the alternative scenario are left unaccounted for. In addition, Rakel G2 will involve indirect tax distortion, especially in connection with the loss of public revenues from spectrum auctions.

Rakel G2 also involves considerable distributional impacts. Some of these are connected to tax funding, including infrastructure costs and user costs of the project, as well as the induced distortion in the tax system. Other distributional impacts relate to user benefits and indirect impacts, building further on the related non-monetized analyses.

Overall, the infrastructure project involves a redistribution to actual and potential users of emergency and preparedness services from taxpayers and receivers of welfare arrangements that alternatively would have been funded. Furthermore, Rakel G2 may contribute to improved mobile coverage in rural areas. If the project is funded by loans rather than grants, it will imply a redistribution to the current population from the future population.