analysys mason

Critical communications for public protection and disaster relief

Cost and time estimates for a new Swedish PPDR network

28.2.2018

Amund Kvalbein and Harald Wium Lie

www.analysysmason.com

Title	PPDR Network costs Cost and time estimates for a new Swedish PPDR network
Date and version	February 28th 2018 Version 1.0

This report is written by Amund Kvalbein and Harald Wium Lie with help from Jon Ivar Kroken and Charles Murray in January 2017 - February 2018.

The report has been developed for Telia Sweden. The analysis contained in this document is the sole responsibility of Analysys Mason and does not necessarily reflect the views of Telia.

Analysys Mason AS
Tjuvholmen allé 19
0252 Oslo, Norway
Tel: +47 920 49 000
www.analysysmason.com

Introduction and summary

The public protection and disaster relief (PPDR) sector has a strong need for robust, secure and flexible mobile communications. Today, authorities in many countries are planning new PPDR networks based on the LTE standard, which is rapidly becoming the dominant technology in commercial mobile networks. MSB has been asked by Swedish authorities to produce more detailed cost estimates for building a dedicated network for PPDR users. The public debate around the next-generation communications solution for PPDR users will be more enlightened if comparable cost estimates for a solution based on commercial networks is available. The objective of the project is to develop and present a time and cost estimate for a separate ("dedicated") state-owned PPDR network and compare this to the cost of building a solution based on a commercial network.

Analysys Mason has advised Norwegian and Danish authorities regarding the economics of future PPDR operating models. In both projects, the main alternatives were a new, dedicated PPDR network and a PPDR network based on commercial LTE networks. The Norwegian project also included an analysis of "non-priced effects" such as network security, robustness, capacity and functionality. The cost model presented in this analysis is based on the models developed for Norway and Denmark and adjusted to Swedish conditions as objectively as possible. In the Swedish model we have also included additional investment for extra high robustness and security levels. This analysis does not include an evaluation of "non-priced effects", but we have modelled the commercial alternative in order to provide PPDR users with a solution of at least the same quality as a dedicated network. Figure 1 shows the overall assessment of lifetime net costs for the two alternatives.

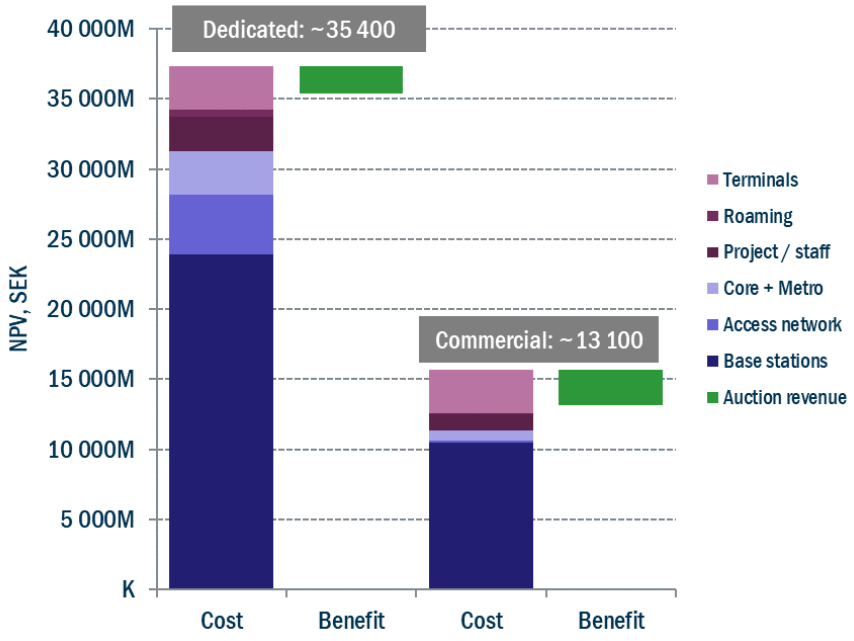

Figure 1. Overall assessment – Base Case including high robustness and security

The dedicated alternative has an estimated net cost of around SEK 35,400 million. Gross costs are estimated at around SEK 37,400 million and estimated benefits (auction revenues) are around SEK 2,000 million. Costs associated with the deployment and operation of base stations are clearly the most important cost element and represent almost 65 % of the gross cost at around SEK 23,900 million. The access, transport and core networks represent around 20 % of gross costs, while manpower and terminals are a little less than 10 % of gross costs each. Other costs, such as roaming and IT systems, play a relatively small role.

The commercial alternative has an estimated net cost of around SEK 13,100 million. In other words: The estimated lifetime net cost of a commercial alternative is less than 40% of a dedicated network. A dedicated network has lower costs in almost all areas: At base stations alone, estimated savings are over SEK 10 billion. The costs of access, metro and transport networks are significantly lower. A commercial operator will need additional personnel in order to provide high-quality PPDR services, but compared to a dedicated operator the organizational cost is also low. The basic driver for the large differences in net costs between the alternatives is that the commercial alternative is mainly based on an existing, almost fully deployed LTE-based mobile network. Even with large investments in robustness and security, it is simply much less expensive to upgrade an existing network to provide PPDR communications services than what it is to build a new LTE network from scratch.

Our cost modelling is based on building a 4G PPDR network using the LTE standard. We have not included costs associated with upgrading to future standards such as 5G. The cost of building a 5G network, especially when using higher radio frequencies that 5G is normally associated with, will be much higher than our estimates for a 4G network. The relative cost advantage of a commercial alternative is likely to be even higher in a 5G scenario.

1 Background and methodology

The objective of the analysis is to evaluate costs and benefits associated with establishing and operating a solution for Swedish PPDR users in two main alternatives:

- A separate ("dedicated") state-owned PPDR network
- A solution based on a commercial network.

Authorities in many countries are planning new PPDR networks based on the LTE standard, which is rapidly becoming the dominant technology in commercial mobile networks. As the figure below shows, most authorities we know will base the PPDR solution on commercial networks, but this does not mean that all elements must or should be provided by private companies. In the Nordic countries, no other country has selected a state-owned network that the Holmgren-report[1] recommended.

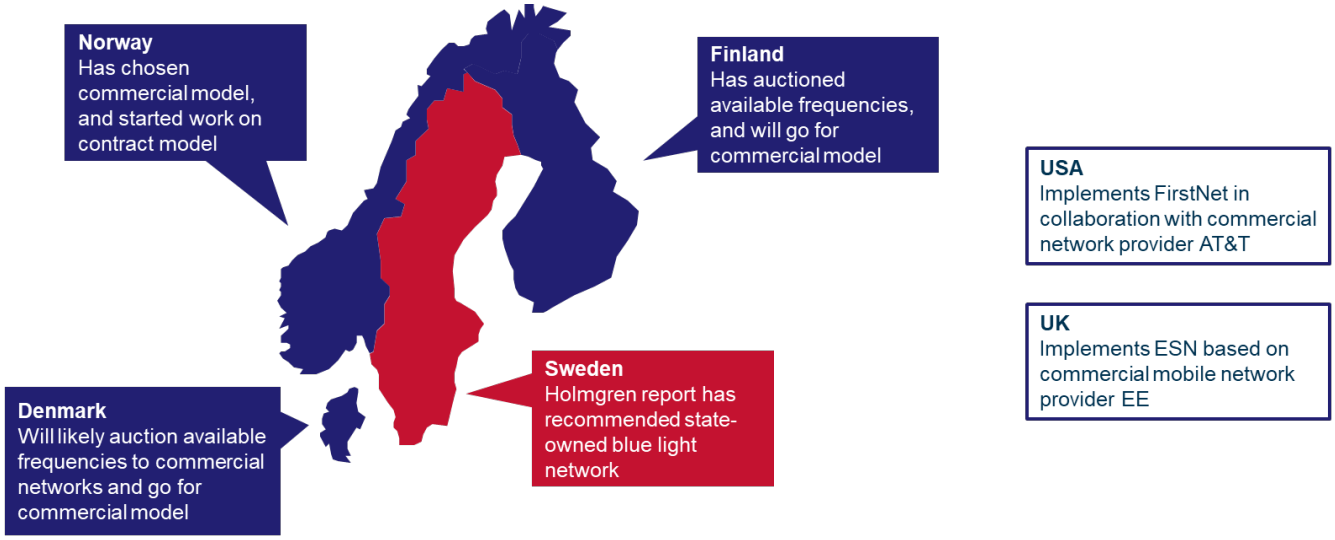

Figure 2. LTE-based PPDR networks in the Nordic countries

Analysys Mason has advised Norwegian and Danish authorities regarding the economics of future PPDR operating models. In both projects, the main alternatives were a new, dedicated PPDR network and a PPDR network based on commercial LTE networks. The Norwegian project also included an analysis of "non-priced effects" such as network security, robustness, capacity and functionality.

The cost model presented in this analysis is based on the models developed for Norway and Denmark and adjusted to Swedish conditions. In the Swedish model we have also included additional investment for extra high robustness and security levels. The main focus of the analysis is "priced effects" – factors that can be quantified in a reasonable manner. We have followed the guidelines for Cost-Benefit Analysis (CBA) issued by the Norwegian Directorate of Financial Management[2] which are broadly

[1] Swedish Ministry of Justice: Kommunikation för vår gemensamma säkerhet – ansvarsfrågor och samordning, May 2017

[2] Norwegian Ministry of Finance: «Prinsipper og krav ved utarbeidelsen av samfunnsøkonomiske analyser», April 2014

similar to Trafikverkets ASEK framework[3]. This analysis does not include an evaluation of "non-priced effects", but we have modelled the commercial alternative in order to provide PPDR users with a solution of at least the same quality as a dedicated network.

In the base case, we have used 30 years as the expected life of the PPDR network. This is shorter than the ASEK guidelines which apply mainly to roads and railways, but still a long period for a mobile network. However, a substantial part of the costs is linked to upgrading and deploying physical base stations, which is an argument for such a long period of analysis. The analysis period should also be long enough to cover at least the entire license period for the frequencies.

The CBA is based on present value calculations. In line with the ASEK guideline, we have used a real, annual discount rate of 3,5 percent as the basis for the analysis. There are several reasons for discounting future values. One argument is that Sweden is becoming more prosperous for each year, which indicates that there is more pressure on production resources today than it will be in the future. Another argument is that the future is uncertain and that one should therefore focus more on what is happening in the near future.

All costs are specified in 2018 kronor excluding value added tax. We have adjusted for general price developments using the consumer price index (KPI), and used 1.7 per cent per year for future KPI growth. Also, we have taken into account that the cost of building construction costs has exceeded consumer prices in recent years and is likely to be somewhat higher in the coming years. In the future, we have assumed an annual growth of 3.2 per cent[4], ie 1.5 percentage point above the consumer price index. Furthermore, we have assumed a real wage growth of 0.5 per cent per year.

[3] Analysmetod och samhällsekonomiska kalkylvärden för transportsektorn, ASEK

[4] For reference, the Swedish «Byggnadsprisindex» has on average increased by more than 4% per year since 1992

2 System overview and elements

A cost analysis requires a description of the system to be analysed. This chapter contains an overall description of a LTE-based mobile network and the items we have included in the cost analysis to provide data services over a mobile network that uses frequencies in the 700 MHz-band. A mobile network consists of several items shown in Figure 3, and the cost analysis is structured according to this figure.

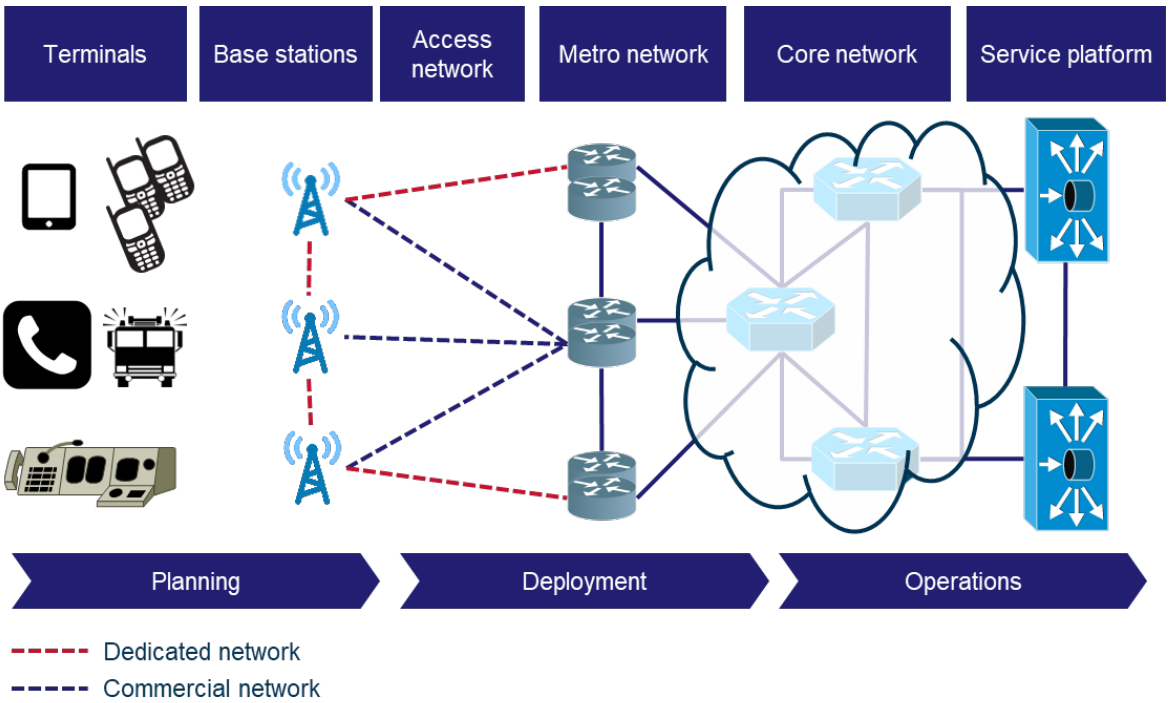

Figure 3. System overview

2.1 Terminals

Terminals are shown in the far left of Figure 3. For most end users, this means a handheld mobile phone, but there may also be fixed terminals in vehicles, vessels and aircrafts. In addition, there are control rooms - such as emergency services and police operations centres - where access to mobile networks is of great importance.

In all outcomes, we have included costs associated with the purchase and delivery of 75,000 terminals for emergency and emergency workers at a cost of SEK 10,000 per unit. This is high, but many of the terminals will be specialized models with robust physical design. Also, there will be a cost of distribution and programming of the terminals. Furthermore, we have assumed that 25 per cent of the terminals require installation at a cost of 2 500 kronor per install and that each terminal is exchanged on average every five years. Total, discounted costs throughout the analysis period will be around SEK

3,100 million in both alternatives. Note that if a dedicated emergency network is to be realized with non-standard frequencies (such as 700 MHz band outside the duplex band), the price of end-user equipment is likely to be much higher.

2.2 Base stations

Terminals communicate with radio units that are often called "base stations". In Sweden and many other countries, the 450 MHz band and 900 MHz band were used early for mobile communication - hence the terms "NMT 450" and "GSM 900". With technological development and ever-increasing demand for mobile services, new frequency bands have been put into use. For mobile data traffic, access to the 800 MHz band - the so called Digital Dividend band - was important for realizing high coverage and high capacity. Today, it is common to expect a downstream speed of more than 20 Mbit/s in an LTE network. With the previous generation mobile network - UMTS - expected downstream capacity was around 2 Mbit/s.

The 700 MHz band has good coverage characteristics with potentially long range and good penetration of walls and other obstacles. In addition, the frequency band is relatively wide, so that overall capacity in mobile networks will increase significantly. This will likely result in higher speeds to end users. In both alternatives we have assumed that broadcast stations are established with equipment that uses the 700 MHz band to carry traffic to and from the terminals. It is important to note, however, that we believe a commercial operator will deploy a 700 MHz-based service for its commercial users.

The table in Figure 4 shows the number of base stations, types of base stations and associated costs in the different alternatives. The rest of the chapter will use this as a reference.

Alternative		Dedicated	Commercial
Base Stations (eNode B)			
No of sites	# sites	7,250	8,250
New, greenfield sites	# sites	2,650	250
Greenfield with mast	# sites	1,250	50
Rooftop	# sites	1,250	50
Specific objects	# sites	150	150
Existing sites	# sites	1,600	8,000
New, leased sites	# sites	3,000	-
Capex per site (incl. robustness uplift)			
New sites			
Greenfield with mast	SEK initial	1,785,000	1,750,000
Rooftop	SEK initial	1,085,000	1,050,000
Specific objects	SEK initial	1,435,000	1,400,000
Leased / existing sites			
Civil + robustness upgrade needed*	SEK initial	854,000	NA
No civil upgrade except robustness**	SEK initial	717,500	400,000
Reinvestment	% of intital per year	10%	10%
Opex per site			
New, Greenfield sites	SEK / year	100,000	100,000
Existing sites	SEK / year	5,000	5,000
New, leased sites	SEK / year	50,000	50,000

** In a dedicated network, we estimate that ~78% of leased and existing sites will need to upgrade the hut, mast, battery or power supply due to installation of the additional LTE equipment. A commercial network will already have the necessary LTE equipment in place, but will need a robustness upgrade.*
*** In "No civil upgrade", the dedicated network will incur costs for LTE radio, antennas, planning and installation. In the commercial network, we have allocated SEK 400 000 per site for robustness upgrades.*

Figure 4. Base stations – number of, types of and associated costs

The number of base stations is usually the most important cost driver for a mobile network and is also a significant variable in our analysis. In a dedicated network, we have used a total of 7,250 base stations from information in the Holmgren[5] and MSB/Trafikverket[6] reports. In a commercial network, we have used a total of 8,250 base stations where 8,000 are existing LTE station and 250 sites will be built especially for a PPDR network.

In addition to differences in the number of base stations, there will be significant differences in types of base station. In the cost model we have used three types of transmission stations:

- New, greenfield site: A base station is established in a location with no existing mobile infrastructure.
- Existing site: The site is already established by the relevant operator, but a dedicated network operator will have to install the 700 MHz radio equipment.
- New, leased site: The site is already established by another operator which means that the PPDR operator will incur lease costs and in many cases upgrade costs.

Costs for the different types of transmission stations vary greatly, and within the same type of establishment different outcomes will have different costs. The table below shows estimated costs for establishing a greenfield base station for a commercial operator.

[5] Swedish Ministry of Justice: Kommunikation för vår gemensamma säkerhet – ansvarsfrågor och samordning, May 2017

[6] MSB and Trafikverket: Redovisning av kostnads- och aktöranalyser m.m, Jan 2018

Greenfield site with mast	SEK per unit
Radio + license	200,000
Antenna	50,000
Hut	150,000
Mast	250,000
Battery + rectifier	50,000
Planning	50,000
Installation	350,000
Power	250,000
BTS robustness increase	400,000
Sum	1,750,000

Figure 5. Costs – greenfield base station with mast – commercial operator

In sum, the cost of deploying a greenfield base station is estimated at around SEK 1,35 million for a dedicated network. The estimates are based on input from mobile network professionals. In addition, we have included SEK 400,000 per station for robustness measures. Examples of this are the expansion of battery capacity or the strengthening of access lines.

For a dedicated network, the cost is likely to be somewhat higher. A commercial operator has a continuous and in some cases international purchasing volume. This is likely to impact actual prices for equipment purchase, planning and installation. A dedicated operator will not have these advantages – at least not to the same extent. We have therefore assumed that a new, greenfield site will cost around SEK 35,000 more for a dedicated operator.

The high cost of greenfield base stations implies that mobile network builders will primarily search for existing base stations. In many cases there will be space available, but it will be necessary to upgrade larger or smaller parts of the site. It is difficult to get accurate estimates of what such a cost would be, but after conversations with experienced network builders we have included this cost as 40 percent of the initial cost (excl. robustness increase) for greenfield stations. In addition to this cost, we have added SEK 300,000 in robustness measures per site for a dedicated operator and SEK 400,000 per site for a commercial operator.

Finally, there are some base stations where necessary changes can be made without any special upgrades. Here, however, there will be differences between the outcomes: In the commercial alternative, we have assumed that the provider has already established an LTE network with equipment that supports the 700 MHz band. The only cost in this outcome will then be SEK 400,000 per site in robustness measures to fulfill obligations that the operator has in license or agreement with the authorities. A dedicated operator will have to purchase, plan and install own radio equipment and antennas on each site. We have assumed that the dedicated operator's existing sites are operational in today's TETRA network. Based on this, we have added SEK 300,000 per site for extra robustness in the dedicated network as opposed to SEK 400,000 per site for a commercial operator.

There is every reason to believe that the proportion of greenfield base stations will vary between the alternatives. There are many owners of radio sites in Sweden, and we do not know about any overall overview of availability and capacity. However, we are confident that a commercial operator will mainly use existing base stations where equipment is already established and only general robustness

measures are needed. However, we have included 250 new sites in areas such as tunnels and train stations where the commercial LTE coverage is not good enough.

For a dedicated network, we have assumed that the 1,600 existing sites will be used for a new network, another 3,000 sites will be leased, and that 2,650 sites will be new sites. Among the 4,600 leased and existing sites, we have estimated that ca. 80% of these will need will need to upgrade the hut, mast, battery or power supply due to installation of the additional LTE equipment.

In total, the estimated lifetime cost for base stations vary significantly between the alternatives. While the commercial alternative has a lifetime cost of ca. 10,500 million SEK, the corresponding cost for a dedicated network is more that 23,900 million SEK.

2.3 Access network

In wired networks, it is common to define access networks as the connection between the end user and the nearest operator code. In mobile networks, the access networks is normally referred to as the link between a base station and the nearest operator node. Mobile access networks can be built in several ways, and we have made different designs based on different outcomes. In Figure 3, the blue access network line represents a star network where one base station has one connection to an operator node. This is a common design for commercial mobile networks. Most Tetra networks have a more robust access network where each base station has two access network links as shown with a red, dotted line in Figure 3. This means that a cutoff of one link does not have to mean that the base station loses connection to the rest of the network. Access networks can be realized in the form of a point-to-point radio connection ("radio link") or using wired networks. Over time, the proportion of wired networks, and especially fibre networks, will probably increase due to new demands from new generation of mobile technology. Fibre networks has normally significantly higher capacity than radiolinks.

Rebuilding access networks in commercial networks from star structure to ring structure will drive large investments, and we have assumed that the star structure is retained in the commercial alternative. As mentioned, we have included SEK 400,000 in robustness measures at the base station. In many cases, it may make sense to use part of these funds to establish ring structures.

In some ways, the analysis of access networks is similar to the analysis of base stations: How often can you use a connection that is already established and how often do you need to establish new and expensive connections? After talks with experienced professionals, SEK 200,000 has been used as the average cost of establishing a new access network link. In addition, we have calculated the annual cost of operations and reinvestments at 10 percent of the initial cost.

In cases where you rent a similar approach, SEK 3,500 per month is used as reference cost. This is probably higher than what usual prices are today. However, we have adjusted the cost since the share of access links in rural areas will probably be somewhat higher in an PPDR network than for commercial networks.

In the dedicated alternative we have assumed that new access lines are established for half of the base stations and that the rest is being rented. We believe that this is a higher proportion than the case in the

current TETRA network. Increased demand for capacity, increased fibre coverage in general and a probable time pressure in implementing the project are drivers for a higher proportion of leased lines.

In the dedicated alternative we have not taken into account that RAKEL network has established a large number of radio links. We believe that a dedicated network will require a complete replanning of the network. Furthermore, we take it for granted that the RAKEL network will live in parallel with a new PPDR network for several years.

In the commercial alternative, we have assumed that access networks have already been established to almost all base stations. For these, 75,000 new PPDR users will incur low or no additional costs in the access network. We have included a cost of SEK 80 per month per access line. This is a fraction of the reference cost of 3,500 kronor per month, and represents the estimated net share of the total network of customers in a public network. For the 250 new sites in the commercial alternative, we have, like the dedicated alternative, assumed an initial cost of SEK 200,000 for access networks together with an annual cost of operation and reinvestments at 10 percent of the initial costs.

In total, the estimated costs vary considerably between the alternatives. While the commercial alternative has a total cost of around SEK 170 million, the cost is estimated to around SEK 4.2 billion in a dedicated network.

2.4 Metro, transport and core network

In an LTE-based mobile network, one will establish metro nodes that serve several base stations. In the dedicated alternative, where the access network is designed in a ring structure - we have assumed that the operator will establish two metro nodes for every tenth broadcast station. Then 1,450 nodes are needed. Furthermore, we budget a cost of SEK 200,000 per metro node and an annual operating and reinvestment cost of 10 percent of the initial cost. In in commercial alternative, the access network is designed as a star structure, and we have assumed one metro node for every tenth base station. However, these metro nodes are already established[7], so that there will be no or low additional costs associated with metro nodes. However, we have included an "initial cost" of 4,500 kronor per metro node which reflects the increase in the customer base that the PPDR users represent.

The transport network is the connection between metro nodes and key elements such as core network and service platforms. We have not assumed any new, dedicated transport links for a new PPDR network. In the dedicated alternative, we have therefore assumed that each of the 1,450 metro nodes has an average rental cost of 3,500 SEK per month per month.

In a commercial network, it can be argued that the cost of the transport network is equal to zero since the transport links are already established. In some cases, however, one might think that the new emergency network users will require the need to upgrade individual connections. We have therefore included a rental cost of SEK 80 per metro node per month.

[7] Or will be established before launch of the PPDR network

The core network consists of several elements that keep track of traffic and users. A service platform is responsible for the production of one or more services. It is reasonable to believe that a new PPDR network will have its own service platform for mission-critical voice and messaging services, just like the current TETRA networks have. In addition, access to other services such as video and image transmission will probably be an important part of a new PPDR network.

We think the cost of the core network will be the same in both alternatives. We have assumed a separate core network and service platform for PPDR users. We have included SEK 75 million for the purchase and installation of core networks together with an annual cost of operations and reinvestments of 20 percent of the establishment costs. In addition, we have allocated SEK 25 million for purchase of service platform, SEK 50 million for initial Security Operations Centre (SOC) costs, and 10 million in project costs for specification and customization. We have included 10 security experts in the SOC. In addition, there are costs associated with a product management. In a dedicated network, we have allocated five employees to this at an annual cost per employee of SEK 970,000. In a commercial network, we believe that you can reduce the number of employees because you want a lot of overlap with the existing product environment for mobile operators. We have calculated with two additional employees at the same annual cost as in a dedicated network.

In summary, the dedicated alternative has an estimated cost of metro, core and transport networks of approximately SEK 3,1 billion, while the corresponding cost for a commercial operator is around SEK 700 million.

2.5 Organization

It takes a lot of personnel to plan, build and operate a mobile network. There is reason to believe that organizational models and resource needs will vary a great deal between the alternatives. We have chosen to divide the manpower requirements into three groups: Project, Operations, and Staff as shown in Figure 6.

Organization: Number of FTEs	Alternative	
	Dedicated	Commercial
Project (yr 1 - 4)		
Project members	95	50
Share consultants	47%	10%
Operations (yr 2 - 32)		
Operations, security	45	27
Staff & management		
No. of FTE yr 1 - 4	5	2
No. of FTE yr 5 - 32	50	25
Share consultants	25%	5%

Figure 6. Organization

The cost model is based on the establishment of a four-year project to plan and deploy a PPDR network. However, the activities in this project period will vary widely between alternatives. In a dedicated network, a network will have to be planned more or less from scratch: 7,250 radio sites shall be identified, acquired, planned and implemented. This is an ambitious project, and we have assumed that

you need 95 full-time resources ("FTEs") for four years to complete the project. The commercial alternative is easier: 97 percent of 8,250 base stations already exist and the workload will be lower. However, even in a commercial network it will still be necessary to establish core network and service platform. We have allocated 50 FTEs to this and other tasks such as follow-up of an PPDR agreement with public authorities.

After the project period, an operating organization will take charge of daily network operations. However, there will be a need to rig the operating organization well in advance of the completion of the project for testing, training and service launch. We have assumed that this will start in year two. It is also likely that the need for operating personnel will be greater in a dedicated network than in a commercial network. A dedicated network will need dedicated personnel to monitor and manage base stations and access networks. In a commercial operation, all or a large part of this will be taken care of by existing personnel. Both alternatives will need for a separate operating organization for security, terminals, core networks and service platform. Based on this we have roughly estimated the need for operating personnel to be 45 FTEs for a dedicated network and 27 FTEs for a commercial network.

In addition, there will be a need for staff and management. During the project period, the project group will largely function as a staff. Consequently, we have calculated with a small number of staff members during this period. After the project period, a dedicated network will need a staff with the same tasks as today's RAKEL network. We have allocated 50 FTEs to this. In a commercial network, many staff function – such as sales, analysis and HR – already exist. We have therefore reduced the number of FTEs to 25 in the commercial alternative. In our opinion, this allows for thorough follow-up of the PPDR agreements and other tasks.

Figure 6 shows the estimated number of man-years in different outcomes. The figure also shows an estimate of the proportion of man-years that will be carried out by hired consultants. This is an important variable, since the cost of hired consultants is usually quite a bit higher than the cost of permanent employees. In a dedicated network we assume that the use of consultants will be significantly higher than for the commercial alternative. A commercial network will probably have better opportunities to solve project and staff tasks with its own employees than what the case would be for a government organization that would be responsible for a dedicated network.

We have used a cost of salaries and social costs of SEK 970,000 per year for permanent employees. The cost of hired consultants is set at SEK 1.5 million per man-year.

In addition to salary and social costs, we have included costs associated with office rental, IT systems and other costs. In the project period, this cost is roughly estimated at SEK 75 million annually for a dedicated network and 50 million per year in the commercial alternative. Furthermore, we have assumed that the operating organization will have other costs totalling 25 percent of payroll costs and the corresponding share for staff management is 10 percent.

In summary, a dedicated network has an estimated organizational cost of around SEK 2,400 million while the corresponding cost in the commercial alternative is around SEK 1,200 million.

2.6 Auction revenue

The auction value equals the state's revenue from the current frequencies at full competition. In practice, the state will not be able to achieve an auction price equal to the auction value, because the tenders may be at a lower price due to imperfect competition. In this analysis, we will focus on a realistic estimate for auction revenue – the actual revenue that the state will get from the auction and annual fees – and not auction value.

Frequency characteristics are an important driver for the expected auction price for radio frequencies. Different radio frequencies have different reach and ability to penetrate obstacles such as vegetation, rain and house walls. Figure 7 shows that frequencies placed low in the electromagnetic spectrum have a higher expected price than high frequencies. Low frequency spectrum, often defined as frequencies below 1 GHz, has a longer range than spectrum in higher frequency bands. The coverage area of a transmission station is inversely proportional to the square of the frequency. This means that a mobile network using the 1 GHz band requires twice as many broadcast stations as the 700 MHz band, the 2 GHz band requires eight times more and the 2.6 GHz band requires 14 times as many broadcast stations. We have already discussed the significant costs associated with base station deployment, and this is the main reason why low frequencies are so valuable.

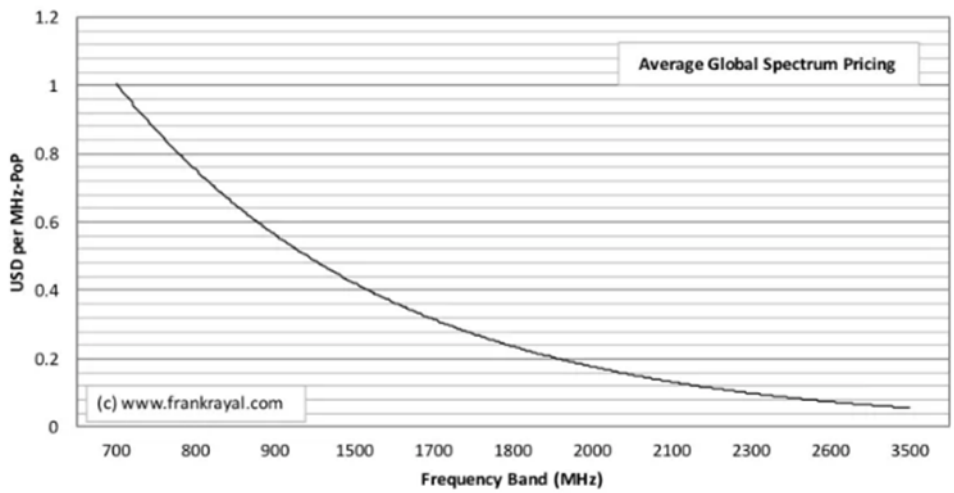

Figure 7. Frequency prices in various frequency bands. Source: Frank Rayal

However, the competitive situation among mobile operators is also an important driver of the expected auction price, and even frequencies can attain very different prices in different markets. In 2015, for example, both French and German authorities conducted auctions of 700 MHz frequencies: In France, the price was € 0.71 per MHz and population, while the corresponding price in Germany was € 0.21. The main reason for this is probably that the competitive climate among mobile operators is tougher in France than in Germany. Figure 8 shows auction prices for relevant frequency bands and markets in recent years.

Year	Country	Frequency band	Auction price €/Mhz/pop	Bandwidth Mhz	€ Auction revenue	Population
2015	France	700	0.71	60	2,798,976,324	66,000,000
2013	Australia	700	1.06			
2015	Germany	700	0.21	60	1,000,445,000	80,620,000
2016	Finland	700	0.20		66,330,000	5,439,000
2011	Italy	800	0.83	60	2,962,500,000	59,830,000
2010	Germany	800	0.73			
2011	France	800	0.69			
2013	Great Britain	800	0.51			
2013	Belgium	800	0.54	60		
2011	Sweden	800	0.41			
2012	Denmark	800	0.26			
2015	Germany	900	0.24	70	1,345,687,000	80,620,000
2011	Italy	1800	0.27	30	477,000,000	59,830,000
2015	Germany	1800	0.30	100	2,405,449,000	80,620,000
2015	Norway	1800	0.64	30	97,553,667	5,084,000
2010	Germany	2600	0.02			
2012	Netherlands	Div	0.63	360		
2013	Norway	800/900/1800	0.23	170	198,300,222	5,084,000
2017	Norway	700	0.45	60	137,268,000	5,084,000

Figure 8. Frequency auctions in relevant bands and markets.

In addition to frequency features and competitive situations, other considerations are often important for auction prices. Population density and access to other frequency bands may play a role. If the market is well served by wired access networks, the value of radio frequencies may be somewhat lower. In addition, general economic prosperity will play a role.

By calculating the realistic expected auction price for 700 MHz frequencies in Sweden, we have taken the following factors into account:

- The 700 MHz band is a valuable band with good features
- High degree of competition among mobile operators
- Low population density
- High broadband coverage in general
- High alternative construction cost
- High economic prosperity

Based on this, we estimate that € 0.40 is a realistic price per MHz and population as long as the bandwidth is 60 MHz and it follows clearly defined coverage commitments with (at least one of) the licenses. Then (one-time) auction price will be around 1.2 billion.

Furthermore, the model is calculated with the following variables:

- Auction price per MHz in a 40 MHz auction is set 15 percent higher than auction price per MHz in a 60 MHz auction due to higher scarcity of frequencies and hence higher competition.
- The auction revenue is calculated for an estimated license period of 25 years, while total costs are calculated over 32 years. Our analysis period will continue for seven years after the license period has expired. We assume that the state is able to achieve a similar auction revenue after 25 years, adjusted for consumer price development and for a reduced period (seven years instead of 25 years).

- We assume that recurring fees will be around SEK 3,7 million in constant consumer prices per year for a 60 MHz frequency block and 67 percent of this for a 40 MHz frequency block.

In total, we estimate SEK 2,550 million in net revenue for a commercial alternative with 60 MHz available, while a dedicated scenario with 40 MHz result in estimated revenues of SEK 1,950 million.

2.7 Roaming costs

Roaming refers to situations when a mobile operator uses another mobile network to provide coverage to subscribers. A dedicated network operator is likely to rely heavily on roaming during the deployment of the dedicated network. In order to estimate roaming costs in the dedicated alternative, we have used the following model inputs:

- 75,000 subscriptions that are brought into the network over a four-year period.
- An eight-year rollout period for the radio network where ca. 900 base stations are deployed every year for a total of 7,250 base stations.
- The share of on-net traffic increases with the share of base stations deployed. After the rollout period, we assume that 99 % of traffic is on-net.
- Monthly data usage of 4 GB per subscription, and a 25 % yearly traffic growth per user.
- A roaming cost of SEK 40 per GB. This is higher than regular roaming costs, but we have assumed that a dedicated operator will insist on priority roaming. Also, we assume a 10 % yearly price decrease in the cost per GB.

Based on this we estimate the lifetime roaming costs for a dedicated operator to be around SEK 500 million. A commercial operator may also have roaming costs, but they are likely to be much smaller since the deployment period is much shorter. We have included SEK 65 million in roaming costs in this scenario.

3 Overall assessment

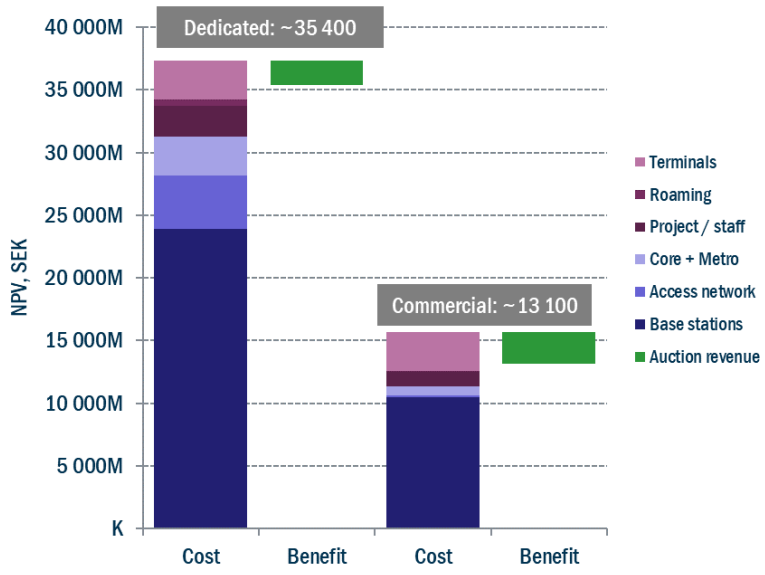

Figure 9. Costs and benefits for both alternatives

The dedicated alternative has an estimated net cost of around SEK 35,400 million. Gross costs are estimated at around SEK 37,400 million and estimated benefits (auction revenues) are around SEK 2,000 million. Costs associated with the deployment and operation of base stations are clearly the most important cost element and represent almost 65 % of the gross cost at around SEK 23,900 million. The access, transport and core networks represent around 20 % of gross costs, while manpower and terminals are a little less than 10 % of gross costs each. Other costs, such as roaming and IT systems, play a relatively small role.

The commercial alternative has an estimated net cost of around SEK 6,300 million. In other words: The estimated lifetime net cost of a commercial alternative is less than 40% of a dedicated network A dedicated network has lower costs in almost all areas: At base stations alone, estimated savings are over SEK 10 billion. The costs of access, metro and transport networks are significantly lower. A commercial operator will need additional personnel to provide high-quality PPDR services, but compared to a dedicated operator the organizational cost is also low. The basic driver for the large differences in net costs between the alternatives is that the commercial alternative is mainly based on an existing, almost fully deployed LTE-based mobile network. Even with large investments in robustness and security, it is simply much less expensive to upgrade an existing network to provide PPDR communications services than what it is to build a new LTE network from scratch.

4 Sensitivity analysis

Figure 10 shows estimated net lifetime costs for both alternatives in various scenarios. The dedicated alternative is marked "D" in the figure, and the commercial alternative is marked "C".

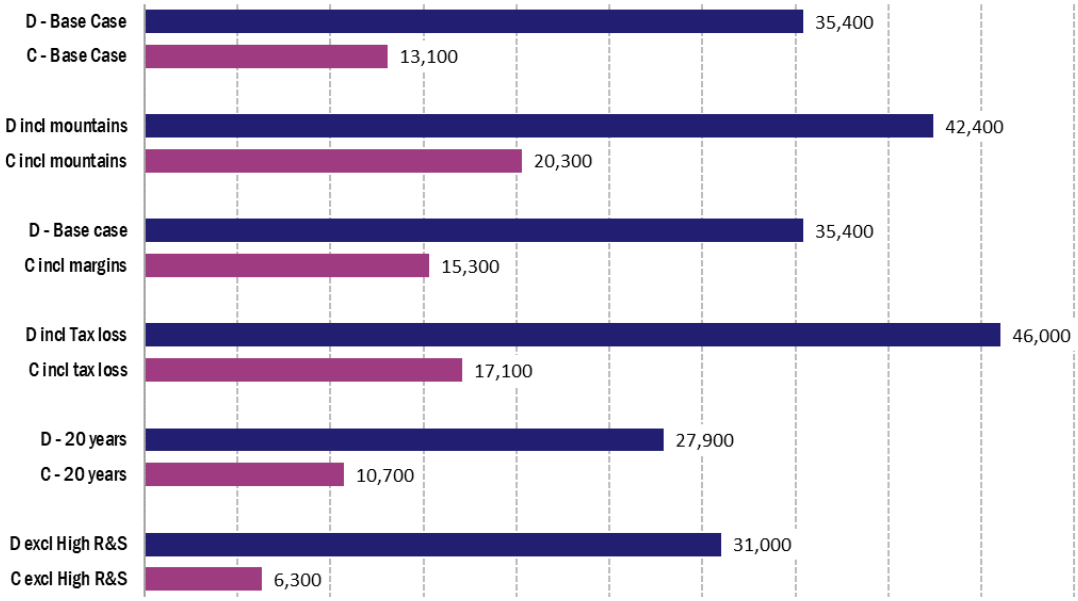

Figure 10. Sensitivity analysis

Coverage in mountain areas

A new PPDR network may need coverage in mountain areas that are not covered by commercial operators today. In this scenario, we have included 1,000 new, greenfield sites at an initial cost of more than SEK 1,7 million in both alternatives. This adds SEK 6 billion to the net cost.

Operator margins

In the base case, we have not included operator margins. A 30 % margin for the commercial operator will add a little over two billion kronor to the net lifetime cost in the commercial alternative. When calculating the margin, we have assumed an ARPU of SEK 150 in the period until 2025 and SEK 600 after 2025. The margin is then calculated as 30 % of estimated revenues and added to the other cost elements.

Deadweight tax loss

Both alternatives cause public spending that must be covered by increased taxes, reduced public spending in other areas, or reduced net savings. This implies both distribution effects and efficiency

effects. The distribution effect means that some groups will become worse off due to higher tax burdens or lower welfare standards. This results in efficiency effects, as resource usage moves away from what is optimal based on the citizens' preferences. This loss of efficiency is referred to as the tax cost or the deadweight tax loss.

Trafikverket's ASEK framework recommends a deadweight tax factor of 1,3 (or 30%) for projects that are financed by the state or municipalities. This is clearly the case for a new PPDR network. When we increase the relevant cost elements by 30 %, the lifetime cost will increase in both alternatives. Since the dedicated network has much higher costs than the commercial network, the effect will be higher for this alternative.

20-year network operations

If we reduce the number of network operations years from 30 to 20 years, lifetime costs will decrease in both alternatives to around SEK 5 billion in the commercial alternative and a little less than SEK 24 billion in the dedicated alternative.

Standard robustness and security

In this scenario, we have added SEK 100,000 as additional investment for all sites instead of SEK 400,000 for commercial sites and SEK 300,000 for most dedicated sites. Also, we have excluded the security uplift with SEK 50 million in initial investments and 10 employees in both alternatives. These measures reduce estimated lifetime costs with SEK 4,400 million in the dedicated alternative and SEK 6,800 million in the commercial alternative.