

Savunen, Tapio; Töyli, Juuso; Mähönen, Petri

## Conference Paper

# Beyond traditional planning: Using real options to navigate uncertainties in next-generation public safety projects

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# Beyond traditional planning: Using real options to navigate uncertainties in next-generation public safety projects

Tapio Savunen<sup>1</sup>

*Aalto University, School of Electrical Engineering, Department of Information and Communications Engineering*

*tapio.savunen@aalto.fi*

Juuso Töyli

1) *University of Turku, Turku School of Economics, Department of Marketing and International Business*

*juuso.toyli@utu.fi*

2) *Aalto University, School of Electrical Engineering, Department of Information and Communications Engineering*

*ext-juuso.toyli@aalto.fi*

Petri Mähönen

*Aalto University, School of Electrical Engineering, Department of Information and Communications Engineering*

*petri.mahonen@aalto.fi*

## Abstract

This study examines the business aspects of mobile network operators (MNOs) in public safety mobile broadband projects using MNOs' 4G/5G networks. It compares incremental and waterfall project management approaches to assess their impact on MNO profitability, public funding requirements, and the management of investment uncertainty through real options. A discounted cash flow model was used to evaluate both approaches from the perspectives of MNOs and government authorities (GAs). The findings show that the incremental project management approach outperforms the waterfall approach for both MNOs and GAs, improving MNO profitability and reducing public funding needs through phased service introduction and user adoption. The choice between project management approaches depends on project goals – whether to prioritise rapid technology replacement or added value for public safety users. This study supports MNOs in optimising financial outcomes in public safety projects, provides strategic guidance for GAs in designing effective public safety procurement processes, and offers policy recommendations for regulation.

**Keywords:** mobile network operator, public safety, public funding, incremental project management, real options

## 1. INTRODUCTION

Public safety agencies – including police, fire and rescue services, and paramedics – depend on reliable wireless communications in their field operations. Historically, these agencies have relied on narrowband land mobile radio (LMR)

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<sup>1</sup> Corresponding author

networks, starting with analogue solutions and later evolving to digital systems such as TETRA, P25, and Tetrapol (Fantacci et al., 2016; Kumbhar et al., 2016). Voice-based push-to-talk (PTT) has been the primary service. Public safety communications have more recently been undergoing a shift towards standardised 4G/5G mobile broadband services, driven by technological advancements and evolving operational needs that LMR systems can no longer fully support. Key requirements include video transfer between field operations and control centres, applications providing useful information to first responders, and mobile field command solutions (Peltola & Hämmäinen, 2018; Yarali, 2020). PTT is expected to be replaced by mission-critical services (MCS), which integrate voice, video, and data (Lair & Mayer, 2017). Public safety mobile broadband improves field operations and enhances efficiency and safety while delivering broader societal benefits, such as lower costs, reduced injuries, and crime prevention (Peltola & Martikainen, 2015). In the United Kingdom, public safety mobile broadband services could increase police productivity by 10% (Grous, 2013), and in the European Union, improved emergency response could save 24 billion EUR annually (Blackman et al., 2014).

With the goal of optimising the cost of the radio access network (RAN) for public safety, there are new business opportunities for mobile network operators (MNOs) as public safety services move to standardised 4G/5G technologies. Beyond standard mobile services, MNO networks can support public safety communications through network enhancements, including extended coverage, improved resilience, and prioritisation mechanisms (Höyhty et al., 2018). Leveraging MNO networks for public safety can generate significant taxpayer savings by eliminating the need for dedicated public safety networks and utilising existing MNO radio frequency bands instead of allocating a separate spectrum (Australian Government Productivity Commission, 2015; Norwegian Directorate for Civil Protection, 2018).

When MNO networks are shared with public safety, MNOs use their existing frequency bands to serve both their regular and public safety users. This approach preserves the spectrum for wider commercial use. With 4G and 5G technologies, service quality can be managed to prioritise public safety on shared bands, enabling reliable service quality for public safety, even when the network is congested. Some countries, including the United States, the United Kingdom, and France, provide additional frequency bands for public safety to supplement MNO spectrum (Savunen et al., 2023).

The current national public safety mobile broadband projects are based on contracts between one or two MNOs and a government authority (GA); other parties may also be involved. These projects follow procurement processes governed by national legislation and relevant directives in the European Union (European Union, 2014). Projects are managed by a GA, such as a Ministry of the Interior, an independent agency, or a government-owned public safety operator (Savunen et al., 2023). A key objective of these procurement processes is to minimise taxpayer costs by fostering competition among MNOs, which helps to reduce prices and limit MNOs' profits.

Public safety requires exceptionally high service availability, reliability, and security – known as mission-critical (MC) requirements – exceeding standard MNO service levels. While MNOs are driven by return on investment and prioritise areas with high revenue potential, public safety services must also cover sparsely populated areas (Yarali, 2020). Meeting MC requirements necessitates significant investments in extending network coverage and hardening network resilience and security. These high costs for a niche customer segment create profitability challenges for MNOs, highlighting the essential role of public funding – which can be substantial in scale (Savunen et al., in press). Notable examples include the United Kingdom's Emergency Services Network (ESN), where EE (part of BT Group), the MNO for ESN, was

awarded a contract worth 895.7 million GBP for 2015–2024 (TED, 2019). In the United States, the First Responder Network (FirstNet) received initial funding of 6.5 billion USD, and AT&T – FirstNet’s MNO – was also allocated a valuable  $2 \times 10$  MHz frequency band (U.S. Department of Commerce, 2017).

In ongoing national public safety mobile broadband projects, European initiatives aim to rapidly replace narrowband networks with 4G/5G services, utilising MNOs’ existing networks, which are upgraded and enhanced to support MC services. This approach requires substantial upfront investments and the full-scale deployment of public safety services once technology migration begins. An alternative strategy, as seen with FirstNet, combines existing narrowband LMR networks and new mobile broadband services, enhancing traditional voice services with data-rich applications (Savunen et al., 2023).

The differing objectives of European projects and the FirstNet project in the United States influence their management approaches. European projects reflect characteristics of the waterfall<sup>2</sup> project management approach, which progresses through sequential phases – requirements, design, implementation, testing, and maintenance (Alshamrani & Bahattab, 2015). This approach requires public safety user needs and technological solutions to be defined early in the tendering stage, which is challenging due to the evolving nature of MC mobile broadband technologies. To address uncertainty, users may overstate requirements, which raises costs. MNOs, in turn, may include substantial risk premiums to meet strict coverage and availability requirements and ensure financial viability, further increasing total project costs and the need for public funding. In addition, mobile broadband as a new technology platform can open opportunities for MNOs to develop new services and expand their business – opportunities that are often difficult to anticipate during the tendering stage and may only become apparent once services are introduced and in use.

FirstNet adopted an incremental project management approach, where development progresses through smaller, manageable increments that are each planned, developed, and tested separately. This approach introduces regular decision points, enhancing flexibility and allowing adjustments based on user feedback and evolving technologies (Larman & Basili, 2003). For example, network coverage extensions and resilience hardening measures can evolve over time. Incremental project management can reduce uncertainties in public safety projects, lowering an MNO’s risk and the associated risk premium, as well as potentially reducing project costs and the need for public funding.

According to Savunen et al. (in press), in public safety projects using the waterfall project management approach, public funding – defined as payments to an MNO for RAN coverage extension, hardening, and maintenance – must cover 59% to 93% of the total RAN enhancement costs for the MNO to reach a zero net present value (NPV). The required funding share varies based on the selected business model and the population density of the country. Achieving a positive NPV would require even more funding.

The substantial public funding required under the waterfall approach raises the question of whether the incremental project management approach could lower the need for public funding while still supporting MNO profitability by reducing uncertainties and enabling new opportunities. Moreover, European public safety projects following the waterfall

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<sup>2</sup> The terms *waterfall* and *incremental* project management approaches originate from software development. However, they are widely recognised and effectively illustrate different approaches to structuring a project. Therefore, this study applies these concepts to public safety projects as well.

approach have experienced delays and remain in the implementation stage, falling short of their original schedules. In contrast, FirstNet, which applies an incremental project management approach, has been operational since 2018 and now supports a broad user base along with a substantial portfolio of certified devices and public safety applications (see Section 4.1 for details).

The incremental project management approach enables decision-making throughout the project lifecycle. It also provides a suitable foundation for applying real options. Real options enhance flexibility by representing the managerial opportunities to make strategic decisions during the project – such as expanding, delaying, scaling down, abandoning, or adjusting project outputs and production methods – in response to new information about markets, technologies, or financials. In contrast to passive project management, which adheres to a fixed plan, real options enable management to actively steer the project throughout its execution (Brealey & Myers, 2003).

This study analyses the financial impact of adopting an incremental project management approach in public safety mobile broadband projects, focusing on MNOs' project profitability, and the need for government public funding. We compared the waterfall and incremental project management approaches to determine whether their financial differences are significant from the perspective of the MNO and the government's public funding needs. The analysis also incorporates real options valuation within the incremental approach to capture the value of managerial flexibility. In addition, we investigated the factors influencing the choice of project management methods in public safety projects, with particular attention to the prerequisites for implementing the incremental approach. The analysis focuses on MNOs' financial outcomes and public funding requirements, excluding the costs associated with parallel LMR systems.

The research questions of this study are as follows:

- What are the factors influencing the choice of project management approach in public safety mobile broadband projects?
- Relative to the waterfall project management approach, how can an incremental approach – when combined with real options – reduce uncertainties in public safety projects, thereby reducing an MNO's risk premium, overall project costs, and the need for public funding?
- What strategic recommendations can be made to MNOs and GAs to reduce uncertainties of public safety projects, the necessary risk premium, and public funding?

This study implemented a quantitative research model featuring discounted cash flow (DCF) modelling and real options valuation (Brealey & Myers, 2003), leveraging the framework, data and results from Savunen et al. (in press). The framework was further expanded to include incremental project management and real options analysis.

The results of this study assist MNOs that are considering entry into the public safety market, as well as GAs planning public safety procurements. Additionally, it provides quantitative insights into MNOs' financials for next-generation public safety services, supporting further research in this area.

This article is structured as follows: Section 2 reviews the relevant literature, Section 3 outlines the research methods and data, Section 4 presents the results, and Section 5 discusses their implications. Finally, Section 6 provides concluding remarks.

## 2. LITERATURE REVIEW

### 2.1. Research on MNO business in public safety projects

Savunen et al. (in press) examined key factors affecting MNO profitability in public safety mobile broadband projects, including business models, investment levels, public funding, contract duration, and business risks. Using DCF analysis and data from expert interviews and ongoing public safety projects in Europe and the United States (FirstNet), the study found that substantial public funding – 59% to 90% of total RAN enhancement and maintenance costs – is needed to reach financial break-even (zero NPV), with even higher funding required for a positive NPV. The single-actor business model used in the United States proved more profitable, driven by a broader service portfolio and, hence, higher ARPU. The study also showed that public safety projects can impact MNOs' core business through changes in market share. Based on the assumption of rapid replacement of narrowband LMR systems, it identified the need for further research into incremental approaches that support LMR coexistence and phased service introduction. Addressing this gap is the focus of the present study.

In another study, Savunen et al. (2023) reviewed five nationwide public safety mobile broadband projects involving MNOs: ESN in the United Kingdom, FirstNet in the United States, Réseau Radio du Futur (RRF) in France, Safe-Net in the Republic of Korea, and Virve 2 in Finland. These projects are either in the implementation (ESN, RRF, Virve 2) or operational (FirstNet, Safe-Net) phases and follow either a multi-actor or a single-actor business model. In the multi-actor model in European projects, MNOs provide mission-critical RAN services, while other functions are typically handled by state-owned operators. In contrast, the single-actor model in the FirstNet project assigns the MNO full responsibility for end-to-end service delivery, including devices and applications. While the single-actor business model offers greater revenue potential and innovation opportunities, it also demands higher investment. The study also noted differing priorities: European projects aim for rapid narrowband replacement, whereas FirstNet focuses on delivering added value to public safety users through data-driven services.

Business risks for MNOs in public safety projects were analysed through a qualitative risk model in a study by Savunen et al. (2024). The findings showed that such risks can increase costs, reduce revenues, and result in contractual penalties, all of which may threaten profitability. A major source of risk is inflexible long-term contracts, which can hinder necessary adjustments during the contract period. However, while inflexibility increases risk, longer contract durations can be beneficial by aligning with the long payback periods of major investments. This was confirmed by findings in Savunen et al. (in press), which showed that longer contracts were associated with higher project NPVs.

### 2.2. Comparison of dedicated and MNO networks in the provision of public safety services

Research has examined various implementation models for public safety services. Studies comparing dedicated public safety networks with shared MNO networks consistently find that shared solutions are more cost-effective while still meeting service quality requirements (Australian Government Productivity Commission, 2015; Blackman et al., 2014; Federal Communications Commission, 2010). The socioeconomic value of different implementation approaches has also been examined (Peltola & Hämmäinen, 2018). An analysis by Hallahan and Peha (2011) compared two MNO-based

models: a commercial-only network and a public-private partnership (PPP) model serving both public safety and commercial users. The PPP model delivered higher NPV across population densities, with NPV per radio cell increasing in more densely populated areas.

### **2.3. Technical aspects of using MNO networks for public safety services**

Research on the technical aspects of the use of MNOs' 4G/5G networks for public safety services has addressed capabilities for differentiating service quality, such as quality of service, prioritisation, pre-emption, and 5G network slicing (Hallahan & Peha, 2013; Höyhty et al., 2018); deployable networks ("tactical bubbles") for local coverage and capacity (Höyhty et al., 2018); cybersecurity and resilience of MNO networks (Suomalainen et al., 2021); 5G sidelink for device-to-device infrastructure-independent communication (Chukhno et al., 2023); and future 6G and cybersecurity in tactical public safety deployments (Suomalainen et al., 2024).

## **3. RESEARCH METHODS**

### **3.1. Quantitative research using various methods**

The researchers used a quantitative approach in this study, specifically utilising the DCF model developed by Savunen et al. (in press) to analyse the profitability of MNOs' business in mobile broadband public safety projects. For the current study, the model was extended to incorporate the incremental project management model and the valuation of uncertainties in network investments, justifying the use of the real options method. Influence diagrams were used to analyse the factors affecting the choice of project management model in public safety projects.

We note that while the DCF model used in this study is a quantitative method, the research questions themselves are qualitative in nature. Given the considerable variation across public safety projects – including differences in national contexts, MNO networks, public safety requirements, and regulatory environments – the potential to produce generalisable and precise numerical results is limited. Consequently, the study's findings are primarily qualitative, aiming to address the research questions rather than delivering exact figures.

### **3.2. DCF analysis**

DCF analysis assesses investments by discounting future revenue and cost cash flows to their present value using a discount rate, resulting in the NPV. The NPV represents the total value of an investment and helps evaluate profitability and compare different investment opportunities. Companies should consider investments with a positive NPV. Alongside the NPV, key metrics that are also commonly used include the internal rate of return (IRR), which is the discount rate that makes the NPV zero, and the payback period, which shows the time required to recover the initial investment (Brealey & Myers, 2003).

In this study, the DCF valuation offers several advantages: It captures long-term value creation from infrastructure investments, reflects intrinsic value based on projected cash flows, and is appropriate for financial modelling when comparable market data is unavailable.

### 3.3. Real options

Real options represent the flexibility managers have to adjust investment decisions under uncertainties. In projects, they allow modifications throughout the life cycle, including options to expand, delay, scale down, abandon, or adjust outputs and production methods (Brealey & Myers, 2003). Real options theory has been widely used in mobile communications literature to assess business expansion opportunities and managerial flexibility amid infrastructure investment uncertainties, such as estimating the value of options to delay the transition from 2.5G to 3G networks or to expand 2.5G networks using Wi-Fi as an alternative technology (Harmantzis & Tanguturi, 2007).

### 3.4. Influence diagrams

An influence diagram is a directed acyclic graph composed of nodes and directed arcs. The arcs represent relationships between nodes, which can indicate probabilistic dependencies or influence in decision-making. The nodes include decision nodes (typically represented as rectangles), uncertainty nodes (ovals representing uncertain events), and value nodes (diamonds or hexagons). Influence diagrams are widely used in decision analysis to model dependencies, structure decision problems, and support probabilistic reasoning (Detwarasiti & Shachter, 2005; Howard & Matheson, 2005).

### 3.5. Data collection

This study used the DCF model adapted from Savunen et al. (in press), incorporating data that models MNOs' business in public safety projects. The data for the DCF model was collected from public sources and validated through expert interviews with six senior experts from Telia Finland, Erillisverkot, Airbus Defence and Space, and Spinverse. The MNO business modelling was based on the average financial figures of five reference operators: BT Group/EE, DNA, Elisa, Telia Company, and Vodafone Group. Among them, Elisa (Virve 2 in Finland) and BT Group/EE (ESN in the United Kingdom) are involved in existing public safety projects.

For this study, data on the FirstNet project's progress over the years was gathered from public sources, as detailed in Table 1 in Section 4.1.2.

## 4. RESULTS

### 4.1. Waterfall and incremental project management approaches in public safety projects

#### 4.1.1. European projects using the waterfall project management approach

**Market characteristics:** European national public safety projects serve populations ranging from millions to tens of millions. These projects are governed by GAs, such as the Home Office in the United Kingdom, l'Agence des Communications Mobiles Opérationnelles de Sécurité et de Secours under the Ministry of the Interior in France, and the government-owned public safety operator Erillisverkot in Finland. The GA takes care of project management and the national migration strategy from narrowband to broadband (Savunen et al., 2023). However, user organisations must approve the introduction of new technologies and services.



In Europe, public safety organisations do not have complete autonomy in selecting vendors for MC communications services. In Finland, for example, the *Act on the Operation of the Government Security Network* (2019) grants Erillisverkot the exclusive right to provide MC mobile communications services for public safety organisations.

**Project goal:** In European public safety projects, the primary objective is an expeditious migration from narrowband to broadband technology. This includes the transition from TETRA to mobile broadband in Finland and the United Kingdom and from Tetrapol to broadband in France. In European projects, the waterfall approach features a rapid migration schedule that begins with MNO network enhancements, followed by the swift replacement of narrowband solutions. In the United Kingdom, the ESN project initially aimed to complete migration by December 2019, just four years after awarding the main contracts, including the MNO contract with BT Group/EE (National Audit Office, 2023). In Finland, the original migration timeline was set for 2023–2025 after Elisa was awarded the MNO contract in 2020 (Elisa, 2020; Erillisverkot, 2021). Similarly, following Orange and Bouygues winning the MNO contracts in France in 2022, the French Ministry of the Interior targeted nationwide migration by 2027 (Donkin, 2022; Jackson, 2024). Both the UK and the Finnish projects have faced delays, resulting in postponed migration timelines (Erillisverkot, 2023; National Audit Office, 2023). Beyond technology migration, European public safety projects also aim to enhance first-responder capabilities by introducing new broadband-based services.

**Business model:** European projects follow the multi-actor business model, wherein MNOs provide only MC RAN services and possibly core network services; for details, see Section 2.

#### 4.1.2. FirstNet and the incremental project management approach

**Market characteristics:** The public safety communications market in the United States is highly fragmented, with an estimated 60,000 public safety agencies and more than 10,000 LMR networks (Atkinson, 2020). While FirstNet has been adopted by 56 states and territories (FirstNet Authority, 2021), the market remains competitive, as agencies are not required to use FirstNet services. For example, Verizon, a key competitor of AT&T, offers its own public safety solution, Verizon Frontline (Verizon, 2025).

**Project goal:** The FirstNet project aims to establish a nationwide public safety broadband network that ensures reliable and interoperable communication for first responders. By providing advanced tools and technologies, FirstNet strives to enhance operational efficiency, reduce response times, and improve public safety across the United States (FirstNet Authority, 2021). A key element of this project goal is the transition strategy. Rather than quickly replacing existing LMR networks for voice communication, FirstNet serves as an additional service, providing broadband data capabilities alongside LMR services. Gradual transition allows agencies to incrementally adopt the new technology as it develops and as users become familiar with its capabilities. It is important to note that public safety agencies independently determine their communication solutions and decide when to replace narrowband technology (Savunen et al., 2023).

Table 1 demonstrates the incremental progression of the FirstNet project. After being awarded the contract in 2017, AT&T launched secure broadband services for public safety users within a year. Key components included a dedicated core network, end-to-end encryption, and a 24/7 security operations centre. The implementation of Band 14 network – a frequency band allocated for public safety – also began. Network deployment was incremental, with new capabilities, applications, and devices being introduced alongside an increasing number of public safety agencies subscribing to

services. Deployable network solutions – also called tactical bubbles – have been crucial for enhancing local coverage and capacity during critical public safety operations and in the event of network service outages (Suomalainen et al., 2021).

Improving network coverage across the United States remains a long-term effort. In 2023, AT&T completed its initial five-year deployment, including Band 14, and already, in 2024, the FirstNet Authority made a significant investment decision for a full 5G upgrade and further coverage enhancements.

***Business model:*** The FirstNet project is based on the single-actor business model, and AT&T, as the MNO, provides all end-to-end public safety services, including devices and applications (see Section 2.1).

**Table 1.** FirstNet project progress

Year, month	Time spent	Description
2017, March	0	AT&T was awarded a public–private partnership contract to build and maintain FirstNet public safety broadband network <sup>1</sup>
2017, October	7 months	FirstNet application developer program launched <sup>2</sup>
2018, March	1 year	AT&T was granted permission to begin deployment of a nationwide B14 network for public safety throughout the U.S. <sup>3</sup>
2018, March	1 year	FirstNet service launched for public safety with dedicated LTE core, end-to-end encryption, and 24 × 7 security operations centre <sup>4</sup>
2018, June	1 year, 3 months	FirstNet dealer program launched <sup>5</sup>
2018, July	1 year, 3 months	<b>Status:</b> B14 added to 2,500 radio sites, 10,000+ more sites planned, including 1,000+ new sites <sup>6</sup>
2018, July	1 year, 3 months	Deployable network solutions called <i>Satellite Cell on Light Trucks</i> launched; mobile radio cells with satellite connection and own power supply <sup>6</sup>
2019, May	2 years, 2 months	New deployable solutions called <i>Flying Cells on Wings</i> <sup>7</sup>
2019, May	2 years, 2 months	<b>Status:</b> 600k connections; 7,250 PS agencies and organisations; B14 deployed in 600+ markets (a total of 734 cellular market areas in the U.S.) <sup>8</sup> and more than 50% of the coverage target achieved <sup>7</sup>
2021, January	3 years, 10 months	LMR / FirstNet PTT gateway launched; high-power user equipment solution available <sup>9</sup>
2021, February	3 years, 11 months	<b>Status:</b> 2M connections; 15,000 PS agencies and organisations; coverage 2.71m square miles; 90% of the B14 coverage target achieved <sup>10</sup>
2022, February	4 years, 11 months	5G available in 40 cities and 35 stadiums and venues <sup>11</sup>
2022, February	4 years, 11 months	<b>Status:</b> 3M connections; 19,500 PS agencies and organisations; coverage 2.81m+ square miles; population coverage more than 99% <sup>11</sup>
2022, December	5 years, 9 months	<b>Status:</b> 4M connections; 23,000 PS agencies and organisations; 95% of the B14 deployment completed <sup>12</sup>
2023, March	6 years	AT&T completed its initial five-year deployment of the FirstNet network on time <sup>13</sup>
2024, January	6 years, 10 months	FirstNet Authority's investment decisions: \$6.3 billion for the full 5G network upgrade, plus \$2 billion, including coverage improvements <sup>14</sup>
2025, January	7 years, 10 months	<b>Status:</b> 6.7M connections; 29.5k PS agencies and organisations; 175 apps; 885 devices; coverage 2.97M square miles (U.S. land 3.53M square miles) <sup>15</sup> ; 180+ deployable network solutions <sup>16</sup>

Note: B14 = Band 14; PTT = push-to-talk; PS = public safety;

1: FirstNet Authority (2021); 2: AT&T (2017); 3: FirstNet Authority (2018a); 4: FirstNet Authority (2018b); 5: AT&T (2018a); 6: AT&T (2018b); 7: AT&T (2019); 8: Federal Communications Commission (2020); 9: AT&T (2021a); 10: AT&T (2021b); 11: FirstNet Authority (2022); 12: Savunen et al. (2023); 13: FirstNet Authority (2024a); 14: FirstNet Authority (2024b); 15: Central Intelligence Agency (n.d.); 16: FirstNet (n.d.)

#### 4.1.3. Factors influencing the choice of project management approach in public safety

The three factors examined – market characteristics, project goal, and business model – shape the selection of the project management approach, both in European projects and in FirstNet. Among these, the project goal is the primary factor in adopting either a waterfall or an incremental approach, while market characteristics and business model also play supporting roles.

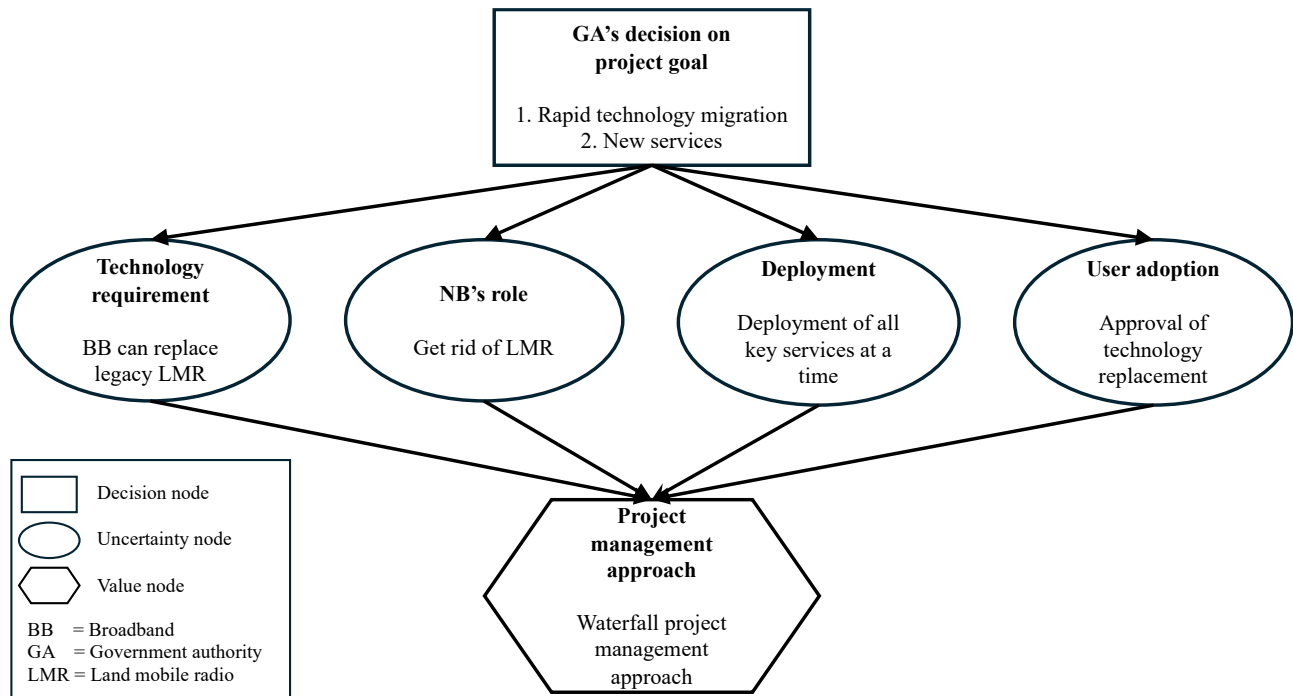
Figures 1 and 2 present influence diagrams that illustrate the relationship between the project goal and the selection of a project management approach. The diagrams present the project from the GA's perspective, representing the government in decision-making. Figure 1 reflects European projects, while Figure 2 focuses on FirstNet. Both diagrams have a single decision node for the project goal, which influences subsequent uncertainty nodes. The final node in the sequence represents the project management approach. The names of the variables are located inside the nodes with bold text at the top, while their corresponding values appear below.

In European projects, where the primary goal is migration from narrowband LMR to broadband technology, the technology requirement necessitates that the new broadband system fully replaces the existing LMR network, effectively phasing out legacy technology. The deployment strategy focuses on simultaneously introducing all key services that replace narrowband functionalities. Additionally, users must approve the complete technology replacement for public safety field operations. These factors support the adoption of the waterfall project management approach, which structures development into linear, sequential phases, culminating in deployment preceded by comprehensive service verification and approval.

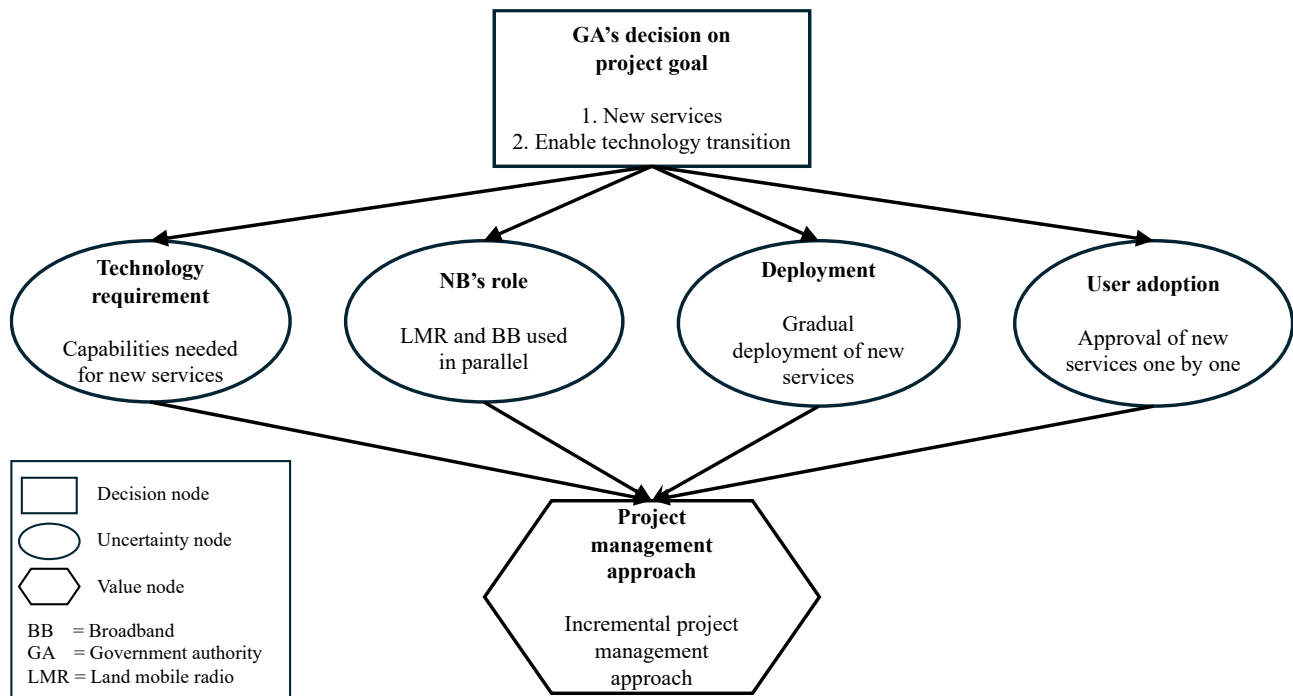
In the FirstNet project, where the primary goal is to provide new supplementary services to first responders, the approach differs from that of European projects. Broadband services are introduced incrementally, while narrowband services remain operational in parallel. User approval is required only for each new service at a time, facilitating the gradual development and deployment of technologies. This approach aligns with the incremental project management approach, which enables development in smaller parallel phases and allows for the continuous integration of user feedback into the process.

The other factors examined – market characteristics and business model – also influence the choice of project management approach. In a fragmented market with numerous independent user organisations, as seen in the United States, a rapid migration strategy is challenging because organisations independently select their communications technology. This supports a gradual technology transition, making the incremental approach more suitable. The single-actor business model further complements this approach by enabling streamlined implementation through continuous incremental steps. However, a multi-actor business model can also align with the incremental approach, provided the employment of effective integration mechanisms, such as appointing a dedicated integrator.

Practical projects may deviate from formal project management approaches. For instance, in the Virve 2 project, although the migration period was postponed from its original 2023 target, the launch of the *Virve 2 Data* subscription in 2022 introduced an incremental element to the project (Erillisverkot, 2023).



**Figure 1.** Influence diagram: Relationship between project goal and project management approach in European public safety projects



**Figure 2.** Influence diagram: Relationship between project goal and project management approach in the FirstNet project

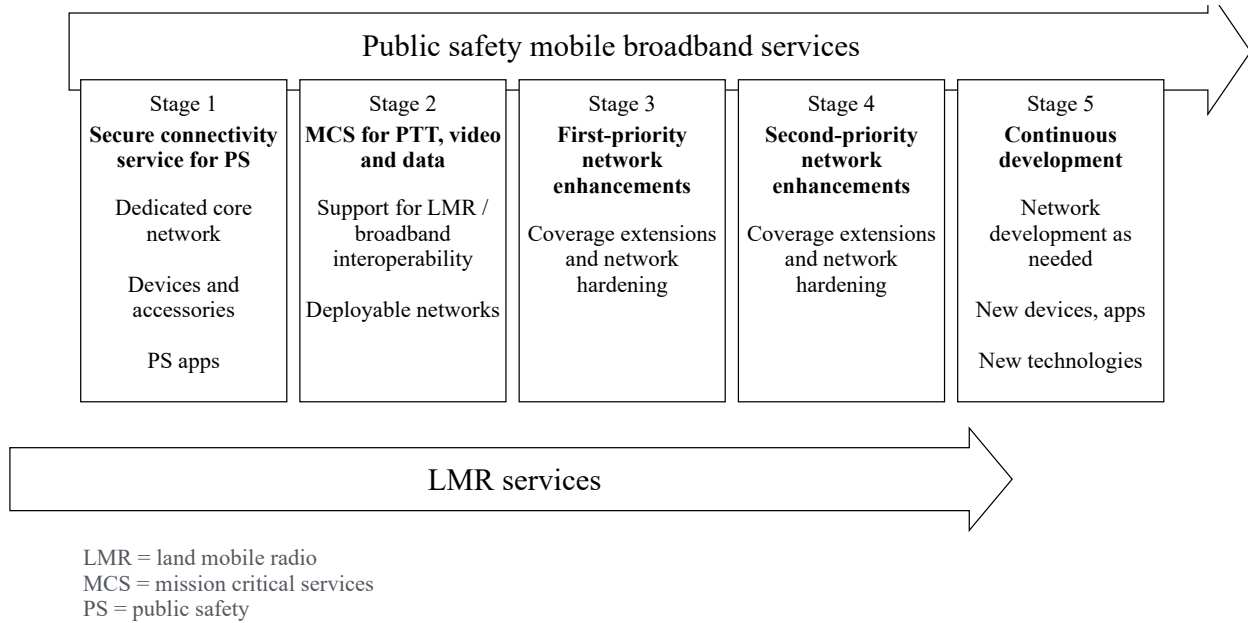
## 4.2. Applying the incremental project management approach in public safety

The FirstNet project example in Section 4.1.2 demonstrates how service introduction can occur early in the project – within just one year of contract award in the case of FirstNet – while network deployment progresses gradually alongside increasing user adoption. It also highlights the added value of the use of broadband services, while narrowband LMR services remain in use. Furthermore, the example underscores that coverage improvement is an ongoing long-term effort that necessitates the incorporation of user feedback.

Beyond these findings from the FirstNet project, incremental approaches enable early risk detection and mitigation. Continuous assessment and response enhance a project’s ability to manage uncertainties, minimising setbacks and ensuring smoother execution. A key measure is maintaining continuous communication among stakeholders, which enhances the early identification of potential risks (Bierwolf et al., 2017). In public safety projects, this can be applied to RAN enhancements through incremental network extensions and hardening. Ongoing user engagement supports feedback collection, guiding further improvements based on user value and technological advancements. It can also uncover demand for additional services, creating opportunities for MNOs to expand their offerings and address new user groups.

Figure 3 depicts a five-stage concept for applying the incremental project management approach in public safety projects, incorporating findings from the FirstNet project and highlighting opportunities for user feedback, early risk mitigation, and integration of technological advancements in RAN enhancements. This concept represents one possible approach, although other variations are also feasible. The first of five stages introduces a secure connectivity service for public safety and a portfolio of devices, accessories, and public safety applications. A key technical enabler is a core network dedicated to public safety, end-to-end encryption, and essential customer services. Stage 2 introduces MCS for PTT, video, and data, with interoperability support for legacy narrowband LMR networks. This enables users to enhance their LMR PTT with broadband capabilities and extended coverage. Additionally, the range of supported devices and applications is continuously expanded throughout the project’s lifecycle.

The network enhancements are divided into two stages: Stage 3 focuses on first-priority enhancements, while Stage 4 addresses second-priority enhancements. This approach allows for the early deployment of network extensions that deliver the most user value. Furthermore, user feedback and technological advancements can be incorporated into the planning of Stage 4, reducing the risk of ineffective investments. Network availability is further supported by the deployable network solutions introduced in Stage 2. It is important to note that network deployments can begin at the start of project implementation; Stages 3 and 4 represent the completion of the enhancements. The final stage marks the beginning of continuous development, driven by user needs and emerging technologies, such as new network generations, devices, applications, and other innovations.



**Figure 3.** A five-stage concept for implementing incremental project management in public safety projects

#### 4.3. Real options for managing uncertainties in public safety projects

Public safety projects require substantial RAN investments to meet stringent MC requirements. RAN expenditures represent the largest cost for MNOs in these projects, necessitating significant public funding to make these projects financially feasible for MNOs. RAN investments include new radio sites for coverage extension and network hardening through redundant transmission links and additional power backup capacity at radio sites (Savunen et al., in press).

Building 4G/5G network enhancements for public safety involves several uncertainties. Unlike narrowband networks, which require relatively few radio sites due to low-frequency operation, high terminal transmission power, and external antennas, broadband networks operate at higher frequencies, necessitating more base stations and increasing the risk of blind spots. Additionally, beyond coverage, sufficient capacity is essential for high-bitrate applications, such as real-time video, with varying requirements across different applications and use cases (Airbus, 2024). These factors introduce significant uncertainties in planning coverage and network hardening enhancements. Additionally, while there is extensive experience in deploying narrowband public safety networks, the use of 4G/5G technologies for MC needs remains relatively new and untested. For example, 5G network slicing enables service differentiation based on quality requirements (Höyhty et al., 2018), but its application in nationwide critical services is still limited. In addition, long public safety project durations introduce further uncertainty due to technological evolution. For instance, advances in low Earth orbit (LEO) satellite constellations and declining service costs may offer new opportunities to extend rural coverage alongside terrestrial networks (Höyhty et al., 2022).

Another area of uncertainty in public safety projects is the MNO's service portfolio. Mobile broadband, as a new technology platform, enables a range of services beyond traditional voice-based PTT, supported by high data rates, smart

devices, and a rich mobile ecosystem. However, many of these opportunities become apparent only after services are launched and used, making it difficult to assess the full business potential at the tendering stage.

The uncertainties associated with planning RAN investments in advance and the MNO's evolving service portfolio pose challenges for the contract between the MNO and the GA. If the MNO is required to commit to fixed and demanding service levels – such as coverage, capacity, and availability – and a predefined set of services, a common but costly response is to include a high-risk premium in cost estimates. This may lead to unnecessarily expensive RAN enhancements, increased public funding needs, and reduced profitability for the MNO – ultimately resulting in a suboptimal outcome for both parties.

Real options refer to the flexibility in project management that allows changes during a project's lifecycle, helping to manage uncertainties and improve adaptability in project execution. It allows project management to incorporate new information, emerging technologies, and market changes throughout the project lifecycle (Brealey & Myers, 2003). In the context of a public safety project's investment strategy, real options enable the project management to defer the final investment decision until more information is available at later stages. However, due to a predetermined decision-making schedule, the decision must be made within the specified timeframe, regardless of the available information. Real options enhance project flexibility, allowing parties to avoid high-risk premiums that could increase public funding and reduce the profitability of the MNO.

The real options approach can be integrated into the concept of the incremental project management approach in public safety (Figure 3). The distinction between first-priority and second-priority network enhancements is assumed to be based on their respective levels of uncertainty. The first-priority enhancements, characterised by a low risk of inefficient investment, can be planned well in advance and implemented as scheduled. Conversely, second-priority enhancements are characterised by high uncertainty and require thorough analysis before implementation. The analysis should take place in close cooperation with users by systematically gathering feedback about the services, coverage, and service availability once the services are introduced and additional experience informs users' reflections. If the collected data indicates that initial estimates for these enhancements were excessive, or if new technologies have emerged, plans can be revised accordingly – potentially reducing the required investment. Additionally, new service needs can be incorporated into the project as they are identified, and once suitable solutions are developed and available.

#### **4.4. DCF model**

##### **4.4.1. Applying a DCF model to compare waterfall and incremental project management approaches**

A DCF model was used to enable a financial comparison of the waterfall and incremental project management approaches. This model represents an MNO's business within a public safety mobile broadband project at the national level and incorporates MNO-specific, project-specific, and market-specific parameters. The model incorporates annual revenue and cost cash flows across the entire project lifespan, capturing the MNO's revenues, investments, and other project costs.



The DCF model is based on the framework developed by Savunen et al. (in press), which analyses the MNO's public safety business from a financial perspective using a waterfall project management approach. Details on the data used in the framework are provided in Section 3.5. The key parameters of the framework, defining market, project, and MNO-related characteristics, are presented in Table 2. The MNO-related parameters were derived from the average financial figures of five reference operators (see Section 3.5). For this study, the framework was extended to incorporate an incremental project management approach and real options analysis.

The original framework supports both sparsely and densely populated country scenarios, acknowledging that MNO network investments for public safety are generally higher in sparsely populated areas. As population density increases, the NPV per radio cell improves – shifting from negative in rural areas to positive in urban areas (Hallahan & Peha, 2011). This study focuses on a sparsely populated country scenario, as the higher RAN investments make the differences between the waterfall and incremental project management approaches more apparent.

The original framework also included two business model variants: multi-actor and single-actor. This study adopted the single-actor model, in which the MNO delivers the full range of public safety services. This choice supports a more comprehensive financial assessment and is better aligned with the incremental approach, as a single actor managing all services provides more flexibility to adapt to project changes. As a result, the present analysis excludes certain elements of the original framework, such as the multi-actor business model and a densely populated country.

**Table 2.** Key parameters of the DCF model (Savunen et al., in press)

Figure	Value
Population of the country	30 million
Number of mobile subscriptions in the country	45 million
Number of public safety users*	225,000
Corporate income tax rate	21.5%
Inflation rate	2.0%
Price erosion of wireless telephone services	−1.0%
MNO's market share of the mobile market	31.5%
Number of MNO's mobile subscribers	14,175,000
Proportion of PS users in the country vs. MNO's mobile subscribers	1.6%
MNO's ARPU, postpaid customers	21.84 euro
MNO's WACC	6.6%
MNO's EBITDA%	35.1%
MNO's personnel cost per employee per year	67,852 euro
Number of MNO's existing radio sites	17,000

\*Services are also used by other critical organisations, such as government agencies supporting public safety;  
 PS = public safety; ARPU = average revenue per user; WACC = weighted average cost of capital;  
 EBITDA = earnings before interest, taxes, depreciation, and amortisation

In the single-actor business model used in the current DCF analysis, the MNO is responsible for delivering all services, including end-to-end connectivity, applications, and devices and accessories (see Table 3). At the heart of public safety

services is connectivity – essentially a mobile broadband service – which forms the foundation for MCS (MCPTT, MCVideo, and MCData) and other public safety applications. This connectivity is classified as MC grade, offering enhanced reliability compared to consumer-grade services through extended coverage, improved network resilience, and hardened cybersecurity. In the single-actor model, the MNO provides an MC end-to-end connectivity service encompassing both RAN and upper-layer services. Public safety applications typically require data rates starting from several megabits per second per user to support video streaming and other high-bandwidth tasks<sup>3</sup> (Peltola & Hämmäinen, 2018).

**Table 3.** MNO services in the single-actor business model (adapted from Savunen et al., in press)

MNO Service
MC end-to-end connectivity service
MCS and public safety applications
Devices and accessories
MC = Mission-critical; MCS = Mission-critical services

**4.4.2.Scenarios of the DCF model**

The DCF model covers both the waterfall and incremental project management scenarios, with the incremental approach also including two real-option valuation alternatives (see Figure 4). The project is assumed to span 15 years, with the incremental scenarios following the stages outlined in Figure 3, each lasting two years, except for Stage 5, which focuses on network maintenance and continues throughout the project.

<sup>3</sup> The absolute minimum requirement for MCPTT voice communication is tens of kilobits per second per user. In large-scale public safety operations involving numerous first responders, the total required capacity is calculated by aggregating the needs of all users, which can lead to substantial capacity requirements per radio cell (Santiago et al., 2024).

<b>Waterfall project management approach</b>	<b>Incremental project management approach</b>		
All investments before service introduction	<b>Incremental investments</b>		
MNO's risk premium for RAN enhancements: 25%	<b>MNO's risk premium for RAN enhancements: 10%</b>		
First-priority network enhancements: 100%	First-priority network enhancements: 100%	First-priority network enhancements: 100%	First-priority network enhancements: 100%
Second-priority network enhancements – cost vs. estimate: 100%	Second-priority network enhancements – cost vs. estimate: 100%	Second-priority network enhancements – cost vs. estimate: <b>70%</b>	Second-priority network enhancements – cost vs. estimate: <b>70%</b>
Subscribed connectivity services – actual vs. estimate: 100%	Subscribed connectivity services – actual vs. estimate: 100%	Subscribed connectivity services – actual vs. estimate: 100%	Subscribed connectivity services – actual vs. estimate: <b>150%</b>
<b>Scenario I</b>	<b>Scenario II</b>	<b>Scenario III</b>	<b>Scenario IV</b>

**Figure 4.** Scenarios of the DCF model

In the modelling, both project management approaches are based on the single-actor business model and assume a sparsely populated country. The key difference between these approaches lies in the timing of network investments: In the waterfall approach, all investments are made up front – before service launch – whereas in the incremental approach, investments are made gradually in parallel with user adoption. Additionally, while services are introduced earlier in the incremental approach, user adoption is spread over several years.

A detailed list of network enhancement parameters for the waterfall and incremental project management approaches is shown in Tables A.1 and A.2, which can be found Appendix A. These tables present parameters illustrating the technical aspects of network enhancements, such as the share of new radio sites relative to existing sites. The value for each parameter is provided, as well as the division between first- and second-priority enhancements in the incremental approach, and the deployment and maintenance years used in the DCF model. The deployment timelines highlight a key difference between the approaches: In the waterfall approach, all enhancements are completed in the early project years, while in the incremental approach, they are phased gradually over the first eight years.

Another distinction between the waterfall and incremental scenarios is the MNO's risk premium for RAN enhancements. The MNO is assumed to apply a cost-plus pricing method for RAN enhancements, which includes a risk premium. In the waterfall scenario, a 25% markup is applied, while in the incremental scenarios, the markup is reduced

to 10% to indicate lower risk premium. Another parameter related to the project's risk is the project cost, which describes the actual versus estimated project costs for RAN enhancements. In the waterfall approach, the project cost is assumed to be 110%, accounting for unforeseen expenses incurred during the rapid deployment of coverage extension and network hardening. Conversely, the incremental scenarios assume a project cost of 100%, reflecting lower risk enabled by gradual implementation and the integration of user feedback.

Scenarios III and IV illustrate the use of real options in the incremental approach. One option involves adjusting production methods by reducing the cost of second-priority network enhancements. The division between first- and second-priority enhancements is detailed in Table A.2 in Appendix A. A 25% cost reduction is assumed, resulting from the use of new technologies – such as 5G/6G LEO satellite services<sup>4</sup> or 5G network slicing over network boundaries<sup>5</sup> – for building rural area coverage and network hardening, along with refined user requirements defined by user feedback.

Another real option demonstrated in the DCF model involves expanding the MNO's business by increasing the number of MC end-to-end connectivity service subscriptions for public safety users beyond the original assumption. This increase is due to the enhanced capabilities offered by mobile broadband technology compared to traditional LMR networks. In LMR networks, subscriptions are tied to physical radios – typically handhelds or mobile radios in vehicles – and linked directly to the first responder who owns the radio. In contrast, mobile broadband offers more versatile connectivity services, supporting new functionalities and requiring subscriptions for various purposes: smart devices carried by first responders, vehicles, and data-only equipment. Additionally, a first responder may use multiple smart devices. For this real option, a 50% increase in the number of connectivity service subscriptions is assumed relative to the original assumption.

The real option for reducing the cost of second-priority network enhancements is included in Scenarios III and IV, while the option for expanding the number of connectivity service subscriptions is included in Scenario IV. As a result, Scenario IV reflects the case with the maximum impact of real options in the DCF model. The valuation of real options in actual projects depends on various factors; the figures used here aim to illustrate the magnitudes and their influence on financial metrics.

#### **4.5. MNO-centric analysis: Maximising NPV under fixed public funding**

This section presents the results of the DCF model from the MNO's perspective. In this analysis, public funding is treated as a fixed parameter in the tendering negotiations: The GA defines the funding level, while the MNO responds by assessing other project parameters, such as the choice between a waterfall or incremental project approach and the potential use of real options over the project's lifespan. Four scenarios of the DCF model explored these alternatives. The MNO's financial performance is assessed using NPV, IRR, and payback period, with NPV serving as the primary measure.

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<sup>4</sup> 6G systems are expected to deliver global, three-dimensional ubiquitous services that serve both densely and sparsely populated regions. This will require the integration of terrestrial, airborne (e.g. drones and high-altitude platforms), and satellite communications across multiple orbits (Höyhty et al., 2019; Höyhty et al., 2022).

<sup>5</sup> One example of new technologies enabling more efficient building of rural coverage is 5G network slicing, which enables the creation of MC virtual networks across network boundaries. It facilitates seamless roaming with MC services and network sharing across different MNOs and technologies (Telia Company, 2025).

In the MNO-centric analysis, public funding is fixed at 1 billion EUR for the DCF model – a realistic figure chosen to demonstrate how the model behaves across the four scenarios and their impact on the MNO’s financial performance. If the level of public funding were higher or lower, the results would scale proportionally. The chosen approach may also represent a strategic move in tendering negotiations where a proposal is presented to gauge the other party’s response. All public funding figures are expressed as discounted values, calculated using the MNO’s weighted average cost of capital (WACC) of 6.6%.

Figure 5 presents the results of the MNO-centric analysis, showing six bar charts that display the values of six variables across four scenarios, as follows: Scenario I – waterfall approach; Scenario II – incremental approach; Scenario III – incremental approach with a real option to reduce the cost of second-priority network enhancements; and Scenario IV – incremental approach with real options for both reducing the cost of second-priority enhancements and expanding the number of connectivity service subscriptions. For details, see Section 4.4.2.

The MNO’s NPV highlights the contrast between the waterfall and incremental project management approaches. Under the chosen fixed public funding level, the waterfall approach resulted in a highly unprofitable outcome for the MNO, with a negative NPV exceeding 700 million EUR. In contrast, all incremental scenarios yielded a positive NPV, indicating profitability. To make the waterfall approach financially viable for the MNO, public funding would need to exceed the fixed level of 1 billion EUR – approximately 1.9 billion EUR in discounted terms would be required to achieve a zero NPV. The introduction of real options significantly enhances project value: NPV increases from 53 million EUR in the base incremental scenario to 189 million and 324 million EUR in Scenarios III and IV, respectively.

The MNO’s IRR and payback period results are consistent with the NPV analysis. The waterfall approach is not financially viable at the given public funding level. Due to the significant unprofitability, the IRR and the payback period are not reported for the waterfall scenario, as they lack meaningful interpretation. In contrast, the incremental scenarios yielded favourable IRRs – ranging from 9.8% to 24.6% in Scenarios II, III, and IV – clearly exceeding the MNO’s WACC of 6.6%. The corresponding payback periods ranged from 11.0 to 8.4 years. While these may not be outstanding for a 15-year project, they demonstrate that breakeven is achieved well before the end of the project timeline. As with NPV, the inclusion of real options in Scenarios III and IV improves both the IRR and the payback period relative to the base incremental case.

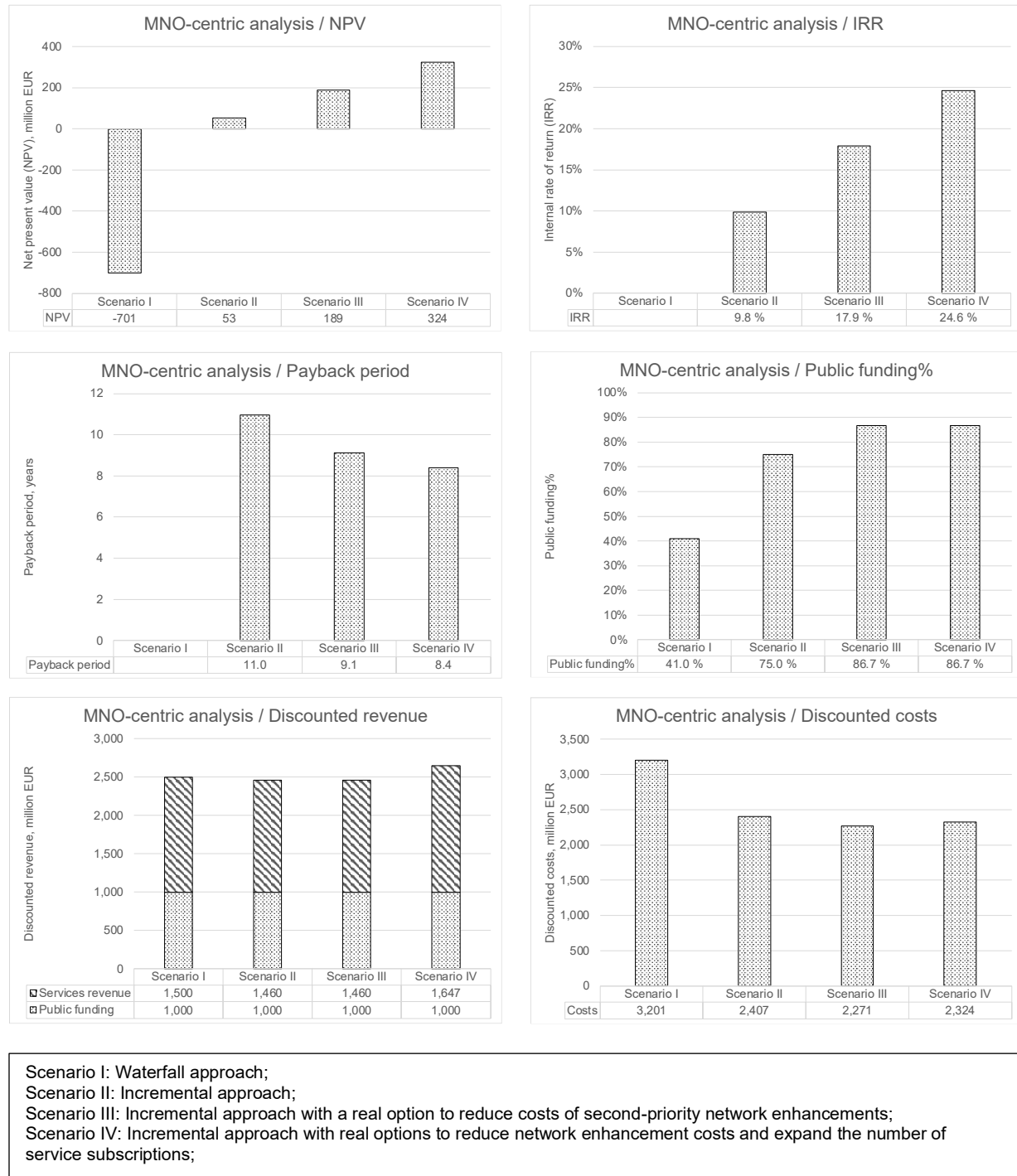
While the NPV, IRR, and payback period reflect the MNO’s financial performance, the remaining three variables provide insights into the underlying factors driving these outcomes. The percentage of public funding – public funding% – represents the share of the MNO’s costs for coverage extension, network hardening, and maintenance that is reimbursed through the contract. A value of 100% indicates full compensation for these costs, including the applied risk premium (10% or 25%). In the MNO-centric analysis, public funding is fixed, while the network enhancement costs vary by scenario, causing the funding share to fluctuate. The waterfall approach, which has the highest costs, results in the lowest public funding percentage. In contrast, as costs are reduced through the related real option, the funding share rises from Scenario II to III. Savunen et al. (in press) emphasised the critical role of public funding in supporting MNO profitability in public safety network investments – a finding reinforced by this analysis.

The discounted revenue is divided into two components: public funding and service revenue. Service revenue consists of subscribed services, as outlined in Table 2. In the waterfall scenario, service revenue is slightly higher than in the base incremental scenario, reflecting faster user adoption compared to the gradual uptake in the incremental approach. Scenario IV shows a further increase in service revenue due to the real option of expanding the number of connectivity service subscriptions, which has a significant positive impact on the NPV compared to Scenario III.

Discounted costs reflect differences in network enhancement investments across project management approaches. In the waterfall approach, all investments are made upfront prior to service launch, while in the incremental approach, investments are phased gradually alongside user adoption, as detailed in Tables A.1 and A.2, found in Appendix A. In Scenarios III and IV, the real option to lower the cost of second-priority enhancements further reduces total network investments.

In real option Scenarios III and IV, a relatively small reduction in costs or increase in revenue results in a substantial improvement in both NPV and IRR. This reflects a high degree of operating leverage (DOL), where modest changes in revenue (or costs) lead to large changes in operating profit. Such sensitivity is characteristic of industries with high fixed costs, such as telecommunications, where network investments represent a major expenditure (Courcoubetis & Weber, 2003; Sarkar, 2018). While the real options in these scenarios enhance profitability, the effect can also be negative: even slight revenue shortfalls or cost increases may significantly erode profits, as the burden of high fixed costs remains unchanged. This underscores the importance for MNOs of maintaining strict cost control and closely tracking revenues to ensure alignment with financial plans. Additionally, a flexible contract enable corrective measures when deviations occur beyond the MNO's control.

To summarise the results of the MNO-focused analysis with fixed public funding of 1 billion EUR, several key findings emerge. First, there is a substantial difference in the MNO's profitability between the waterfall and incremental project management approaches. At the given funding level, the waterfall scenario yielded a negative NPV exceeding 700 million EUR, making the case unprofitable for the MNO, while all incremental scenarios achieved a positive NPV accompanied by a healthy IRR. Second, both real options individually contribute to a substantial increase in profitability, and when both are included, the resulting NPV is approximately six times greater than that of the base incremental scenario. Third, the model demonstrates a high DOL, driven by substantial network investments. This highlights the associated profitability risks and the need for strict cost control and careful revenue monitoring.



**Figure 5.** Results from the MNO-centric analysis with fixed public funding

#### 4.6. GA-centric analysis: Minimising public funding for desired MNO NPV

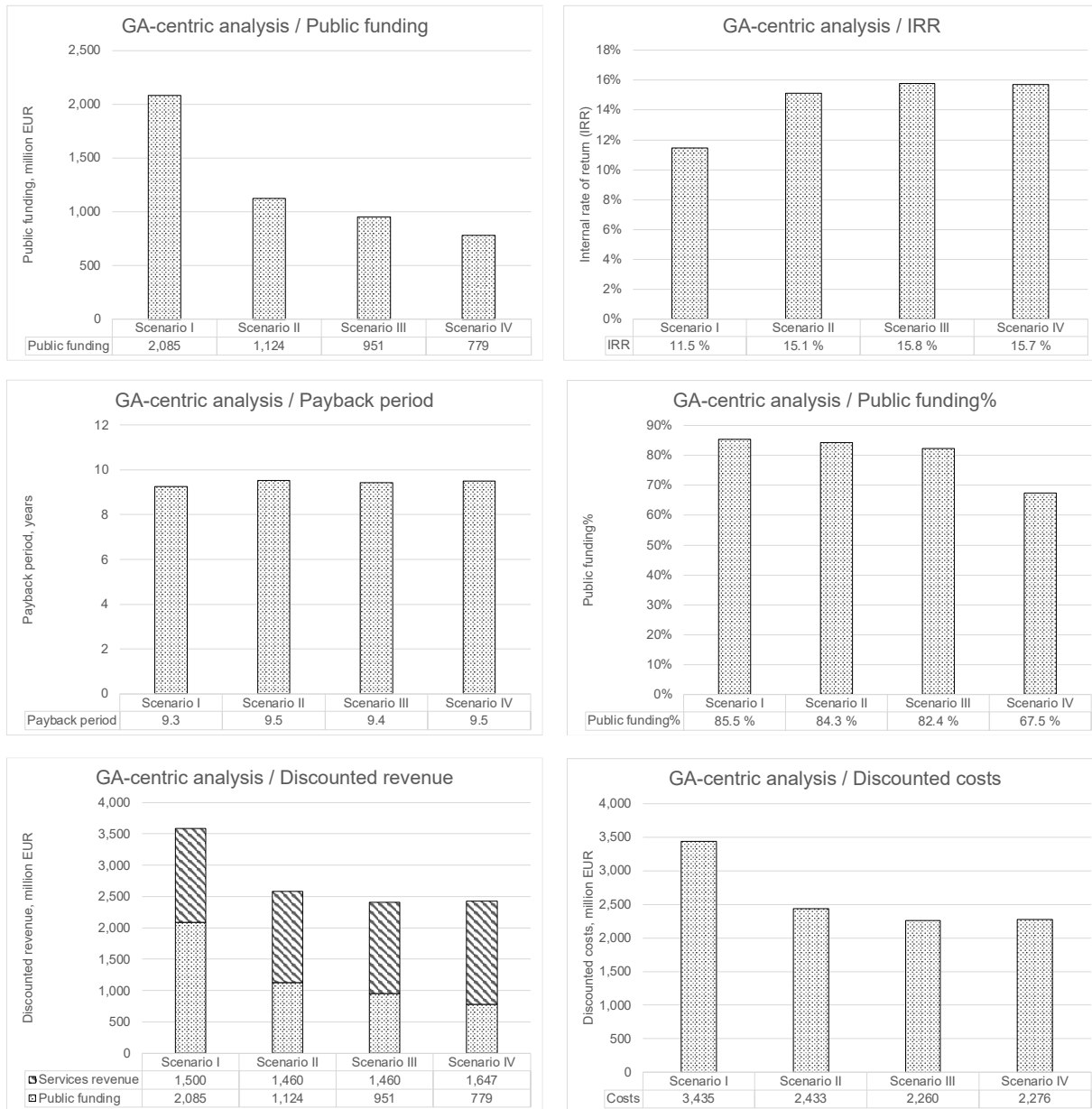
This section presents the GA's perspective, treating the MNO's target NPV as a fixed input. In this GA-centric analysis, the DCF model is used to determine the level of public funding required to ensure the project is financially viable for the

MNO under various configurations. While the logic mirrors the MNO-centric approach, the perspective shifts: the MNO sets a required NPV, and the GA evaluates scenarios to identify the minimum public funding needed. The scenarios and all other DCF parameters remain consistent with the MNO-centric analysis, except that the MNO's NPV is fixed at 50 million EUR – a realistic figure ensuring healthy profitability and an IRR above the MNO's WACC. As in the MNO-centric case, this approach may reflect a strategic stance in tendering negotiations, where proposals are made to elicit a counter-reaction.

Figure 6 presents the results of the GA-centric analysis, displaying the values of six variables across four scenarios. These variables align with those shown in Figure 5 of the MNO-centric analysis, with one key difference: Public funding is included in the GA-centric analysis, while NPV is excluded. This difference reflects the distinct fixed parameters used in the MNO- and GA-centric analyses – fixed parameters are not illustrated in figures. Otherwise, the variables and the logic behind their construction remain consistent.

The results closely reflect those of the MNO-centric analysis. A significant difference emerges between the waterfall and incremental approaches: To achieve the same NPV of 50 million EUR, the incremental approach requires only about 54% of the public funding needed under the waterfall approach. A similar pattern is observed with the inclusion of real options. Both options reduced the required public funding – from 1,124 million EUR in Scenario II to 951 million EUR and 779 million EUR in Scenarios III and IV, respectively. The underlying reasons mirror those in the MNO-centric analysis. Real options further reduced the cost of second-priority network enhancements and boost revenues by expanding the number of connectivity service subscriptions. This also demonstrates the sensitivity to small changes in revenue and costs – consistent with the MNO-centric analysis – with the substantial variations in required funding indicating a high DOL.





Scenario I: Waterfall approach;  
 Scenario II: Incremental approach;  
 Scenario III: Incremental approach with a real option to reduce costs of second-priority network enhancements;  
 Scenario IV: Incremental approach with real options to reduce network enhancement costs and expand the number of service subscriptions;

**Figure 6.** Results from the GA-centric analysis with fixed MNO NPV

#### 4.7. Summary of results

We analysed three factors – market characteristics, project goal, and business model – in national public safety projects in Europe and the FirstNet project in the United States. Among these, the project goal emerged as the primary determinant in selecting between waterfall and incremental project management approaches. In European projects, the goal is a rapid migration from narrowband LMR to broadband, aiming for full replacement of legacy networks within a few years. This objective aligns with the waterfall approach, which follows a structured, sequential process, culminating in comprehensive service deployment. In contrast, FirstNet aims to deliver new, complementary broadband services to first responders while existing narrowband LMR systems remain in operation. This objective is supported by an incremental project management approach, employing phased development, gradual service introduction, and continuous user feedback.

Real options can be applied within the five-stage concept (see Section 4.2) by classifying network enhancements as first- or second-priority based on their level of uncertainty. Lower-risk first-priority enhancements are planned and implemented early, while higher-uncertainty second-priority enhancements are deferred. This phased introduction allows for the incorporation of user feedback and technological advances. If later evidence suggests that initial estimates were overstated or new solutions have emerged, plans can be adjusted – potentially lowering the required investment and the need for public funding. Real options can also facilitate business expansion in public safety projects by offering the flexibility to introduce new services in response to emerging needs and available solutions.

We developed a DCF model to compare the financial outcomes of the waterfall and the incremental approaches. The model builds on the framework developed by Savunen et al. (in press), which combines data from public sources and expert interviews. For this study, the framework was extended to include the five-stage incremental approach and real options analysis, though only a subset of its original capabilities was used.

We applied the DCF model in two separate analyses: one from the MNO's perspective and the other from the GA's perspective. The MNO-centric analysis aimed to maximise profitability with the highest NPV, IRR, and shortest payback period for a given level of public funding. In contrast, the GA-centric analysis focused on minimising public funding while ensuring the MNO achieves a target NPV. These two analyses made it possible to identify the most favourable scenarios separately for the MNO and the GA.

The results of both the MNO- and GA-centric analyses are clear and mutually reinforcing. They reveal a significant difference between the waterfall and incremental project management approaches. The incremental approach proves far more favourable for both the MNO and the GA. In the MNO-centric analysis, the waterfall approach yields a deeply negative NPV (-701 million EUR), whereas the incremental approach results in a positive NPV (53 million EUR), assuming 1 billion EUR in public funding. Similarly, in the GA-centric analysis, achieving a target NPV of 50 million EUR for the MNO requires far less public funding under the incremental approach (1.1 billion EUR) than under the waterfall approach (2.1 billion EUR). This difference is largely due to investment timing. The waterfall approach requires full upfront investment before service launch, driving up costs – especially for network maintenance. In contrast, the incremental approach phases investments in line with user adoption, significantly reducing overall costs. The impact of real options is also consistent across both analyses. A 25% cost reduction in second-priority network enhancements improves financial outcomes for both parties. Similarly, the option to boost revenue by increasing the number of

connectivity subscriptions enhances the position of both stakeholders. Finally, both analyses reveal a high sensitivity to small changes in revenue and costs, indicating a high DOL and underscoring the importance of rigorous financial control throughout the project.

The MNO- and GA-centric analyses are performed independently. In the MNO-centric analysis, public funding is fixed, so improvements in NPV from real options Scenarios III and IV do not impact the funding amount. Similarly, in the GA-centric analysis, the MNO's NPV is fixed, meaning that although public funding decreases in Scenarios III and IV, the MNO gains no additional benefit. This separation of interests does not take into account the need for collaboration or renegotiations during the project. To address this, a contractual mechanism should be established to share the financial gains from real options between both parties. Such an arrangement would motivate both the MNO and the GA to support real options implementation and allow for renegotiations as the project evolves.

## **5. DISCUSSION**

### **5.1. Research contribution**

This study builds on prior qualitative research exploring the use of MNO networks in public safety services, the role of MNOs in such projects, and the associated business risks, as well as on quantitative analyses of MNO profitability in public safety mobile broadband projects. Building on this foundation, the study offers a more detailed examination of the financial implications for MNOs by comparing the waterfall and incremental project management approaches and assessing their impact on both MNO profitability and the public funding required. In doing so, it advances understanding of the financial interdependencies between MNOs and GAs in public safety projects.

### **5.2. Policy aspects**

MNOs' participation in public safety mobile broadband projects entails long-term contractual commitments and substantial investments. Consequently, a clear and stable legislative and regulatory framework is essential for defining roles and managing risks, thereby encouraging MNO participation. In its absence, the risk of post-contractual regulatory changes can create significant uncertainty, discouraging private sector participation (Howell & Sadowski, 2018). Examples of legislation on public safety services include the *Act on the Operation of the Government Security Network* (2019) in Finland, which grants Erillisverkot, the state service operator of Virve 2, the exclusive right to provide mobile MC services to public safety authorities. Similarly, in the United States, the *Middle Class Tax Relief and Job Creation Act* (2012) established the FirstNet Authority to create a network for first responders, and as a result, AT&T was granted the right to provide FirstNet services under a 25-year PPP contract. The U.S. market is competitive; therefore, the FirstNet contract does not provide AT&T with exclusive rights to provide public safety services.

The key findings of this study indicate that the incremental project management approach outperforms the waterfall approach from the perspective of both the MNO and the GA. Across key financial metrics – NPV, IRR, and payback period for the MNO, and the required public funding for the GA – the incremental approach demonstrates significantly

more favourable outcomes. The inclusion of real options was found to further enhance the financial positions of both parties. Realising these benefits, however, requires a regulatory environment that supports long-term partnership-oriented contracts – contracts that are flexible and allow for renegotiation throughout the project lifecycle.

When evaluating whether the regulatory framework adequately supports contracts between MNOs and GAs for public safety projects based on the incremental project management approach and real options, it is important to recognise the relatively small scale of the public safety service market. Public safety users typically represent only 1–2% of a country's total mobile user base (Savunen et al., 2023). As a result, regulatory requirements for this sector differ substantially from those governing the broader MNO market. They should prioritise the sustained delivery of highly reliable public safety services, supported by long-term service commitments and reliable project timelines.

Although European Union regulations do not explicitly prohibit contracts between MNOs and GAs that incorporate the incremental project management approach with real options and flexible, long-term arrangements of 15 years or more, existing competition policies tend to favour shorter-term contracts based on traditional waterfall approaches (European Union, 2014). Public safety projects in Europe are generally modest in scale, typically serving populations from a few million to several tens of millions and involving tens to hundreds of thousands of first responders. In this context, regulatory priorities should align more closely with the specific needs of public safety organisations – particularly the need for reliable service delivery and long-term commitments. Consequently, the European Union may need to reassess its regulatory framework to accommodate more flexible contractual arrangements where these offer greater public value.

### **5.3. Recommendations for MNOs and GAs**

This study demonstrates that the incremental project management model yields more favourable financial outcomes for both MNOs and GAs than the traditional waterfall approach, with real options offering additional gains to each party. As both sides benefit, their business interests can be aligned, providing the basis for making joint recommendations.

A key recommendation for both MNOs and GAs is to adopt the incremental project management approach over the traditional waterfall model, unless there are compelling strategic reasons to justify the latter. The incremental approach offers the flexibility necessary to manage uncertainties inherent in public safety projects, including evolving technologies and the time required for public safety organisations to adopt new solutions due to strict MC requirements. Rigid plans based on rapid user adoption are often impractical, making adaptability essential. Financially, the incremental approach consistently outperforms the waterfall approach – delivering significantly better NPV, IRR, and payback periods for the MNO, and requiring substantially less public funding from the GA. The inclusion of real options further enhances these financial outcomes.

It is important to note that the analysis assumes a single-actor business model, where the MNO delivers the full range of end-to-end public safety services, including MCS applications and devices. This model yields stronger financial outcomes for the MNO compared to a multi-actor model limited to MC RAN services (Savunen et al., in press). Moreover, the single-actor model aligns more effectively with the incremental project management approach, which demands flexibility in planning and good control over end-to-end service delivery. In contrast, multi-actor arrangements introduce coordination overhead and additional costs when managing project changes.

The incremental project management approach underscores the need for a flexible contractual framework that facilitates renegotiations throughout the project lifecycle and ensures fair allocation of financial gains as real options are realised. Such a framework provides both parties with incentives to actively support the implementation of real options. Instead of a traditional transactional contract, a partnership-oriented model is more appropriate. A relational contract offers one such model, fostering mutual trust and collaboration while accommodating dynamic adjustments over time (Macaulay, 1963; Macneil, 1985; Frydinger et al., 2021). Ongoing close coordination with end-users is crucial to maintain alignment on service scope, priorities, and delivery schedules. To fully capture the benefits of the incremental approach, the contract must also be sufficiently long; in this study, a 15-year term was assumed to accommodate the phased deployment of network enhancements and user adoption.

This study has shown that incorporating real options into the incremental project management approach improves key financial indicators. However, it is important to recognise the nature of real options. They are managerial tools designed to enhance flexibility and improve the ability to navigate uncertainty during the project lifecycle. The value they offer is not guaranteed at the outset but may materialise as the project evolves and circumstances change. Consequently, decision-making should not rely solely on the positive NPV derived from real options. If the project does not demonstrate a positive NPV without them, this signals a high-risk setup that may not justify proceeding (Van Putten & MacMillan, 2004).

This study revealed that public safety projects with high network investments exhibit a high DOL, where even modest variations in revenue (or costs) can lead to substantial shifts in operating profit. This sensitivity highlights the importance of securing a robust NPV for the MNO; otherwise, minor deviations from projected financials can quickly erode profitability. To mitigate this risk, financial buffers, stringent cost control, and continuous revenue monitoring are essential throughout the project lifecycle. Moreover, a flexible contractual framework is essential, as it enables corrective actions when deviations arise from factors beyond the MNO's control.

#### **5.4. Limitations of the study**

This study focuses on the financial outcomes for MNOs and the public funding required in public safety projects, with particular emphasis on the MNO's financial performance. Although the costs associated with parallel LMR systems were excluded from the analysis, they are often significant and can be a key driver for accelerating technology migration, given the high operating expenses of LMR systems. However, LMR operating costs vary widely depending on several factors, making it challenging to construct a generalisable and reliable cost model. A feasible approach for incorporating LMR costs in future research would be through case studies of selected countries and completed migration projects. As more financial data becomes available, such studies could offer valuable insights into the financial impact of legacy LMR systems.

This study analyses the MNO and GA perspectives independently, using either a fixed NPV or a fixed public funding. As a result, in the analysis, the financial gains from real options benefit only one party, while the financial position of the other party remains unchanged. This distinction ignores the cooperative nature of project implementation. A contractual mechanism is therefore essential to ensure the fair allocation of gains from real options, thereby providing incentives for both parties to implement them. Future research could investigate the criteria for designing such a mechanism and explore

practical design approaches. One promising direction is cooperative game theory, which offers solution concepts for distributing the payoffs of cooperation among participants, including normative criteria to ensure that these distributions are broadly acceptable. These concepts include single-point solutions, such as the Shapley value and the nucleolus, as well as concepts providing a set of solutions such as stable sets, the core, and bargaining sets (Müller, 2013; Peleg & Sudhölter, 2007).

## 6. CONCLUSION

This study examined MNOs' involvement in public safety mobile broadband projects where MNO networks are shared with public safety users to deliver MC services. The primary focus was on comparing the waterfall and incremental project management approaches in terms of the MNO's financial performance and required public funding, and the ability to apply real options for managing project uncertainties. Using the DCF method across four scenarios, the analysis considered both the perspective of the MNO and the GA. Additionally, the study investigated the criteria for selecting either the waterfall or the incremental approach for public safety projects.

The study's key finding is that the incremental project management approach outperforms the waterfall approach from both perspectives. Across key financial indicators – NPV, IRR, and payback period for the MNO, and the required public funding for the GA – the incremental approach yields significantly more favourable results. Moreover, the incorporation of real options – one aimed at reducing costs in second-priority network enhancements, and one to increase revenue through a higher number of connectivity service subscriptions – further enhances the financial position of both parties.

Another important finding of the study concerns the choice between waterfall and incremental approaches in public safety projects. The project goal was identified as the primary factor guiding this decision. In European projects, the objective of rapid migration from narrowband LMR to broadband has led to the adoption of the waterfall approach. In contrast, the FirstNet project in the United States, which aims to deliver complementary broadband services to first responders while maintaining existing narrowband LMR systems, has favoured the incremental approach – characterised by phased development, gradual service introduction, and continuous user feedback.

The discussion on regulatory aspects highlighted the need for a framework that supports long-term, partnership-oriented contracts with flexibility for renegotiation. As the public safety market typically represents only 1–2% of a country's mobile user base, its regulatory needs differ from the broader MNO market and should prioritise reliable service delivery backed by long-term commitments. Consequently, the European Union should nurture a regulatory framework that encourages flexible, long-term partnership contracts where they clearly enhance public value.

Building on prior research into MNOs' involvement in public safety mobile broadband projects, this study makes a significant contribution by providing a detailed analysis of the financial implications for MNOs. It compares the waterfall and incremental project management approaches, evaluating their effects on both MNO profitability and public funding requirements. In doing so, it deepens understanding of the financial interdependencies between MNOs and GAs in public safety projects.

The analyses for MNOs and GAs were conducted independently, with fixed public in the MNO-centric view and fixed MNO NPV in the GA-centric view. This separation overlooks the need for collaboration and renegotiation during the

project. Future research could explore contractual mechanisms to share financial gains from real options, fostering joint incentives and flexibility throughout the project lifecycle.

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**APPENDIX A – NETWORK ENHANCEMENT PARAMETERS****Table A.1.** Network enhancement parameters for the waterfall project management model

Parameter	Value	Deployment years	Maintenance years
Increase in new radio sites vs. existing sites	9%		
Share of additional radio sites in suburban areas	50%	0 – 3	4 – 15
Share of additional radio sites in rural areas	50%	0 – 3	4 – 15
Share of existing sites with duplicated links	25%	0 – 3	4 – 15
Share of existing sites with additional power backup	25%	0 – 3	4 – 15
Number of deployable network solutions	100	0 – 3	4 – 15

**Table A.2.** Network enhancement parameters for the incremental project management model

Parameter	Value	Share of first priority	Deployment years	Maintenance years
Increase in new radio sites vs. existing sites	9%			
Share of additional radio sites in suburban areas	50%	100%	3 – 5	6 – 15
Share of additional radio sites in rural areas	50%	0%	5 – 8	9 – 15
Share of existing sites with duplicated links	25%	50%	3 – 8	9 – 15
Share of existing sites with additional power backup	25%	50%	3 – 8	9 – 15
Number of deployable network solutions	100	100%	2 – 4	5 – 15

*Share of first priority* indicates the proportion of the network enhancement classified as the first-priority network enhancement