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Factors driving mobile network operator profitability in public safety mobile broadband projects

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ABSTRACT

This study examines the business aspects of mobile network operators (MNOs) in public safety communications projects using MNOs' 4G/5G networks. It analyses key factors affecting MNO profitability in public safety broadband projects, including business models, network investments, public funding, contract length, and business risks. A discounted cash flow model was used, supported by sensitivity analyses, reflecting national public safety projects in the United States and Europe. Based on public data and expert interviews, the model shows that significant public funding is essential for MNO profitability. The single-actor business model used in the United States has been shown to be more profitable than the multi-actor model used in European projects due to its broader service portfolio. Additionally, the findings illustrate how public safety projects can influence MNOs' standard mobile business by affecting market share, with substantial implications for revenue. This study provides a financial model and recommendations to help MNOs maximise profitability in public safety projects and offers strategic guidance for government authorities in designing effective public safety procurement processes. It also presents policy recommendations to further assist with regulation.

1. Introduction

Mobile broadband services are the next step after traditional push-to-talk (PTT) in public safety communications, driven by technological advancements and the need for more advanced capabilities. These include video streaming between first responders and command centres, data services for field operations, and enhanced situational awareness. PTT is expected to be replaced by mission-critical services (MCS) that integrate voice, video, and data, called MCPTT, MCVideo, and MCData (Lair & Mayer, 2017; Yarali, 2020). These capabilities improve public safety efficiency, lower costs, and enhance the safety of first responders and citizens by reducing injuries, mitigating crime through precautionary measures, and saving lives and property (Peltola & Martikainen, 2015). In the European Union, such improvements could save 5 % annually in public safety costs, equivalent to 24 billion EUR (Blackman et al., 2014).

Next-generation public safety services offer new business opportunities for mobile network operators (MNOs). Public safety communications have traditionally relied on specialised narrowband technologies, beginning with analogue systems and later evolving into digital systems such as TETRA, Tetrapol, and P25 (Fantacci et al., 2016; Kumbhar et al., 2016). However, advancements in telecommunications have shifted the development of public safety communications to standardised 4G/5G mobile broadband

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technologies, enabling the shared use of MNO networks by public safety users and other MNO customers, such as consumers and enterprises (Peltola & Hämmäinen, 2018). This is driven by the goal of optimising the costs of the radio access network (RAN) required for public safety. This creates the potential for substantial savings for taxpayers by avoiding dedicated public safety networks and utilising MNOs' radio frequency bands rather than allocating separate bands for public safety (Australian Government Productivity Commission, 2015; Norwegian Directorate for Civil Protection, 2018). Such collaboration between the public and private sectors, often called a public–private partnership (PPP), represents a new and growing trend in public safety communications.

When no dedicated frequency bands are allocated for public safety, MNOs must use their existing spectrum to provide service to both standard customers and public safety users. This approach preserves spectrum availability for other sectors, including commercial mobile services. Service quality management in 4G/5G technologies allows differentiation between public safety and regular customer services on shared bands, aiming to ensure reliable service quality for public safety, even during network congestion. Some countries supplement MNOs' existing spectrum with additional public safety bands, either shared with other customers (as in the United States) or reserved exclusively for public safety (as in the United Kingdom and France), whereas other countries, such as Finland, have no such supplementary public safety bands (Savunen et al., 2023).

The collaboration between MNOs and public entities in delivering public safety services poses profitability challenges for MNOs due to the different objectives of the public and private sectors. Public safety organisations prioritise protecting life, property, and the state, while also minimising costs for end users. Conversely, MNOs focus on profit maximisation and high returns on investment. Public safety demands exceptionally high service availability, reliability, and security – known as MC requirements – which exceed MNOs' standards. Additionally, while MNOs prioritise areas with high revenue potential, public safety services must also cover less populated regions (Yarali, 2020).

National public safety mobile broadband projects are governed by public procurement processes, which adhere to national legislation and, in the European Union, relevant directives (European Union, 2014). Managed by a government authority (GA), such as a ministry of the interior, an independent agency, or a government-owned public safety operator (Savunen et al., 2023), these processes aim to reduce taxpayer costs through competition among MNOs, driving down prices and profits. This creates challenges for MNOs as they seek profitability while meeting the requirements set by the GA.

A key factor influencing MNO profitability in public safety projects is the business model defined by the GA, which varies between Europe and the United States, reflecting different political and regulatory approaches. Regulations in the United States typically favour market-driven solutions, minimal government intervention, economic efficiency, and competition. In contrast, the European Union prioritises consumer rights, public welfare, and equitable markets through a more interventionist regulatory framework (Ahearn, 2008; Fukuyama & Grotto, 2020).

Meeting MC requirements demands significant investments in extending network coverage and strengthening network resilience and security, along with potential IT solutions and personnel costs. These high costs for a small customer segment pose profitability challenges for MNOs, highlighting the importance of public funding in financing necessary investments (Savunen et al., 2023). Such funding can be substantial; for instance, the United Kingdom's Emergency Services Network (ESN) contract with BT Group/EE, the MNO of ESN, has a total value of 895.7 million GBP between 2015 and 2024 (TED, 2019). Similarly, the initial funding of the First Responder Network (FirstNet) in the United States was 6.5 billion USD. AT&T, FirstNet's MNO, also received a valuable 2 × 10 MHz radio frequency band as part of the contract (U.S. Department of Commerce, 2017).

Previous research on MNOs' involvement in public safety mobile broadband projects has primarily focused on technical aspects, with limited attention paid to their business operations in next-generation services. The literature lacks a comprehensive quantitative analysis of MNOs' financial performance in these projects. This study aims to fill this gap by conducting a quantitative financial analysis of MNOs' performance in public safety projects.

This study provides MNOs with insights into the key factors affecting profitability in public safety mobile broadband projects. While this presents MNOs with new business opportunities, profitability depends on balancing revenue and costs – a critical consideration for MNOs aiming to succeed in this market. The analysis covers factors such as business models, RAN investments, public funding, and contract durations, along with the financial impact on MNOs' regular operations and the effects of the business risks of these projects. Based on these findings, this research offers strategic recommendations to help MNOs enhance profitability in this market.

The financial analysis of MNO profitability in public safety projects is also valuable for GAs. By understanding the MNO's financial aspects, the GA can make more informed decisions during procurement to establish a partnership that enables the MNO to successfully deliver public safety services. This insight also enhances dialogue and negotiation between contracting parties.

This study's research questions are as follows:

- What factors significantly influence the profitability of MNOs in public safety mobile broadband projects?
- How do public safety mobile broadband projects affect MNOs' overall financial performance, and what specific risks and opportunities are associated with these projects?
- What strategic recommendations can be derived from the financial performance analysis to help MNOs enhance profitability in public safety mobile broadband projects, assist GAs in planning public procurement, and provide relevant policy considerations?

Techno-economic modelling was used to assess the financial feasibility of MNO investments in enhancing their RAN and other necessary efforts to meet MC requirements and deliver services to public safety users (Smura, 2012). A value network configuration (VNC) was defined for two business models to outline key actors and their relationships (Casey et al., 2010). The profitability analysis was based on a discounted cash flow (DCF) model, supported by a sensitivity analysis (Brealey & Myers, 2003). The DCF model was designed to reflect ongoing public safety mobile broadband projects in the United States and Europe, assuming that the primary goal is the transition from narrowband to broadband solutions, in line with the European approach.

This article is organised as follows: Section 2 is the literature review, Section 3 details the employed research methods and the considered data, Section 4 presents the findings, and Section 5 discusses these findings. Finally, Section 6 offers some concluding thoughts.

2. Literature review

2.1. Technical considerations for the use of MNO networks in public safety services

Research on public safety services using MNOs' 4G/5G networks has largely focused on technical aspects. Research topics include capabilities needed to differentiate the service quality between public safety and an MNO's standard users through features like quality of service, prioritisation, pre-emption, and 5G network slicing (Hallahan & Peha, 2013; Höyhtyä et al., 2018); deployable networks – known as tactical bubbles – for local coverage and capacity (Höyhtyä et al., 2018); information security and the cyber resilience of MNO networks (Suomalainen et al., 2021), and 5G sidelink for device-to-device communication without infrastructure services (Chukhno et al., 2023). Recent research has addressed 6G and cybersecurity in tactical bubbles for public safety (Suomalainen et al., 2024).

2.2. MNOs as an alternative for delivering public safety services

Research has also explored implementation alternatives for delivering public safety services. Comparisons between dedicated public safety networks and shared MNO networks show that shared networks offer a more cost-effective solution while maintaining sufficient service quality (Australian Government Productivity Commission, 2015; Federal Communications Commission [FCC], 2010; Blackman et al., 2014). Implementation options have also been evaluated based on their socioeconomic value (Peltola & Hämmäinen, 2018).

Hallahan and Peha (2011) conducted a techno-economic analysis comparing two MNO network models: one for commercial users (10 MHz band) and one for a PPP serving both public safety and commercial users (20 MHz band). They found that a PPP delivers a higher net present value (NPV) across all population densities, with NPV per radio cell showing a positive correlation with population density.

2.3. MNOs' role in public safety projects

Savunen et al. (2023) reviewed five national public safety mobile broadband projects covering an entire country and involving MNOs. The analysed projects – ESN in the United Kingdom, FirstNet in the United States, Reseau Radio du Futur (RRF) in France, Safe-Net in the Republic of Korea, and VIRVE 2[1] in Finland – are either in the implementation or the operational phase:

- ESN/U.K.: in implementation, with delays and migration postponed, a new contract for the public safety service platform in 2025 (National Audit Office, 2023; Home Office, n.d.; O'Halloran, 2025);
- FirstNet/U.S.: operational since 2018, with a large customer base and a wide range of FirstNet-certified applications and devices (FirstNet, n.d.);
- RRF/France: in implementation, with a nationwide migration target set for 2027 (Jackson, 2024);
- Safe-Net/the Republic of Korea: operational since 2021, 336 user organisations (National Information Society Agency, 2022);
- VIRVE 2/Finland: in implementation, with delays and a migration period from 2025 to 2028 (Erillisverkot, 2023).

These projects can be categorised by their business models, which define the projects' actors and their responsibilities. Fig. 1 illustrates two models, distinguished by the number of actors in the project: *multi-actor* and *single-actor*. The GA typically determines the business model during procurement.

In the multi-actor model, the MNO provides RAN services that meet MC requirements, including coverage extensions and network hardening; some core network services may also be included. Other services are typically provided by a state-owned operator, such as Erillisverkot in Finland's Virve 2 and l'Agence des Communications Mobiles Opérationnelles de Sécurité et de Secours in France's RRF. The multi-actor model, adopted by all European projects considered, generates value for public safety users through integrated services from multiple actors, requiring effective service integration (see Fig. 1).

In European projects, frequency bands are used as follows: Finland's Virve 2 project relies entirely on shared MNO bands without additional allocations for public safety; the United Kingdom's ESN project includes a 5 MHz allocation in Band 40 for air-to-ground communications alongside MNO bands; France's RRF project supplements MNO bands with Band 28 (2 × 3 MHz) and Band 68 (2 × 5 MHz) for public safety coverage extensions, such as deployable networks.

In the single-actor model, as in the United States with AT&T and FirstNet, the MNO provides all end-to-end public safety services, including devices and accessories. FirstNet focuses on delivering added value to first responders through new data applications rather

[1] The name of the Virve mobile broadband project was originally Virve 2.0, but the name was changed to Virve 2.

Service	Multi-actor model	Single-actor model	Service integration
Customer services	Other actors	MNO	
Devices and accessories	Other actors	MNO	
Public safety applications	Other actors	MNO	Public safety user value
MCS	Other actors	MNO	
Core network	Other actors*	MNO	
MC enhancements	MNO	MNO	
RAN	MNO	MNO	

* MNO may also provide some core network services
MC = Mission critical; MCS = MC services; MNO = Mobile network operator; RAN = Radio access network

Fig. 1. Division of responsibilities in single-actor and multi-actor business models (adapted from Savunen et al., 2023).

than targeting a rapid transition from narrowband to broadband. This contrasts with European projects, which prioritise a rapid technological transition. Another unique feature is FirstNet's B14 frequency band allocated for public safety users, 2 × 10 MHz at 700 MHz, although AT&T's regular customers can also use it when not needed by public safety; public safety users can also access AT&T's other bands (FirstNet, 2024c).

The main distinction between the multi-actor and single-actor business models lies in the MNO's role within the value chain, shaping its business opportunities and resource requirements. In the multi-actor model, the MNO is restricted to providing only MC RAN services, limiting its revenue potential. Conversely, the single-actor model allows the MNO to deliver all public safety services, creating opportunities for additional revenue and innovation. The single-actor model also requires more investment. Both models allow the MNO to leverage RAN enhancements for added value to standard customers, creating opportunities to grow market share, increase revenue, and reduce customer churn (Reardon, 2020). The DCF analysis in this study covered both business models.

2.4. MNOs' business risks in public safety projects

Savunen et al. (2024) presented a qualitative model of MNO business risks in public safety projects and found that these risks could increase costs, lead to contractual penalties, and reduce revenue, ultimately threatening profitability. Public safety operations may also negatively affect the MNO's core business, causing market share and revenue losses. Their findings were incorporated into the sensitivity analysis of the DCF model used in this study. The risk domains included are 1) contract risks from inflexible long-term contracts; 2) RAN building delays or budget overruns; and 3) poor service quality for other customers. Triggers for contract-related risk include lower-than-expected average revenue per user (ARPU), fewer users than anticipated, and adverse political or regulatory changes. This risk was analysed through the sensitivity analysis parameters of *number of users* and *contract length.*

It is important to note that although a long contract period, together with an inflexible contract, represent risk for the MNO, a long contract period can also be advantageous due to the substantial investments and the long payback period they require. Additionally, a long contract period in PPP projects is expected to foster innovation (Roumboutsos & Saussier, 2014),

The risk of *RAN-building delays or budget overruns* can arise if the MNO underestimates the required efforts and costs during the tendering phase. Consequences include increased project costs, lost service revenue, and contract penalties due to delayed service introduction. This risk was analysed in the sensitivity analysis using the *project cost* parameter.

The risk of *poor service quality to other customers* emphasises the potential negative impact of public safety services on the MNO's standard customer base. If public safety services degrade service quality for standard customers, they may switch to competitors, reducing the MNO's market share and causing financial losses. This risk was analysed in the sensitivity analysis using the *mobile business growth* parameter to assess opportunities and risks – namely, market share growth or loss.

3. Research methods

3.1. Quantitative research and techno-economic modelling

A quantitative research method was chosen for this study. As research on MNOs' business interests in the public safety market is still in its infancy, quantitative analyses have been limited due to the lack of a robust theoretical framework and sufficient data. However, recent qualitative studies (see Sections 2.3 and 2.4) have established a solid foundation for conducting a quantitative analysis that models the financial characteristics of MNOs' public safety projects.

Techno-economic modelling was chosen because it enabled the evaluation of the financial feasibility of investments in technical systems (Smura, 2012). Given that MNO RANs require technical enhancements and significant investments to meet the demanding service requirements of public safety users, techno-economic modelling was a suitable choice.

A DCF model was developed to address the research questions, which are inherently qualitative, by analysing the key factors affecting MNO profitability in public safety projects and deriving relevant recommendations for MNOs and GAs. Due to the wide variation in public safety mobile broadband projects, their financial outcomes can differ significantly. Therefore, the DCF model does not aim to provide precise numerical figures as general results, as these inevitably vary from project to project.

The steps of techno-economic modelling are as follows: 1) the definition of the market and service, the technology, and the industry architecture; 2) revenue and cost modelling; and 3) DCF model and sensitivity analysis (Smura, 2012). The DCF method, VNC method, and data-collection procedures are detailed in Sections 3.2, 3.3, and 3.4, respectively.

3.2. DCF method

DCF analysis evaluates investments by discounting future cash flows – revenue and costs – to their present value using a discount rate, yielding the NPV. The discount rate reflects the potential return on an alternative investment with a comparable risk profile, representing the opportunity cost of allocating capital to one investment instead of another. The NPV, which is the key outcome of the DCF analysis, indicates an investment's total value, aiding in profitability assessments and comparisons with other investment opportunities. In addition to the NPV, other measures include the internal rate of return (IRR), the discount rate at which NPV equals zero, and the payback period, which indicates how long it takes to recover initial costs. Sensitivity analysis combined with DCF modelling is used to assess how changes in assumptions affect NPV. This enables researchers to evaluate profitability under various risk scenarios, helping quantify and manage project risks (Brealey & Myers, 2003).

When combined with sensitivity analysis, the DCF model offers several advantages over other business-valuation methods commonly used in telecommunications, such as multiples-based valuation (Schreiner, 2009) and market value added analysis (Stancu et al., 2017). DCF analysis emphasises long-term value creation through infrastructure investment, enables detailed risk assessment, and reflects intrinsic value based on projected future cash flows rather than market or peer benchmarks. Additionally, it is a suitable method for financial modelling in the absence of comparative market data.

Table 1
Data collection for the DCF model.

Topic	Items	References
Market and service, technology and industry architecture definitions		
Framework of the model		Savunen et al. (2023)
Business risk scenarios		Savunen et al. (2024)
Revenue and cost modelling		
Market	Corporate income tax rate	Bray (2023)
	Inflation rate, Europe	Eurostat (2024a)
	Price erosion, wireless services in Europe	Eurostat (2024b)
	Number of mobile subscriptions in European countries	ITU (2024)
	Public safety users in a country vs. mobile subscribers	Savunen et al. (2023)
Data of reference MNOs	Key business figures	BT Group, 2024 DNA (2024a) Elisa (2024a) Telia Company, 2024a Vodafone Group, 2024
	Average revenue per user (ARPU)	Padoan (2024) DNA (2024b) Elisa (2024b) Telia Company, 2024b Statista (2024d)
	Weighted average cost of capital (WACC)	ValueInvesting (2024) DNA (2023)
	Market share	Statista, 2024a (the United Kingdom) Statista, 2024b (Finland) Statista, 2024c (Vodafone)
	Number of radio sites	Harrap, 2022 (BT/EE) Traficom, 2023 (Finland)
RAN building and maintenance costs		FCC (2010) Sitowise (2020) De la Cruz, 2023 Interviews with senior experts • Telia Finland (MNO) • Erillisverkot (public safety service operator) • Airbus Defence and Space (public safety solution provider) • Spinverse (business consulting firm)
Public safety service prices and service adoption		FirstNet (2024a) FirstNet (2024b) Interviews with senior experts; see previous list

Note: Currency rate conversions according to European Central Bank rates, March 5, 2024; EUR/GBP: 0.8557 EUR/SEK: 11.64.

DCF analysis has been widely employed in research on operators' business opportunities in wireless services. Notable examples include a financial analysis of the introduction of 3G licensees in Sweden from the perspective of MNOs' profitability (Björkdahl & Bohlin, 2002); an analysis of whether it is economically viable for an LTE operator to provide a 30 Mbps fixed service in rural Spain (Ovando et al., 2015); a comparative financial analysis of 4G service deployment in India using 700, 1800, and 2100 MHz frequency bands (Jha & Saha, 2017); and a techno-economic total cost of ownership analysis of various heterogeneous wireless networks with different base station configurations (Kamboh et al., 2017).

3.3. VNC method

The VNC method analyses and visualises value networks – including technology and industry architecture – in networked business environments, illustrating cooperation to create added value. It provides a systemwide view of relationships at both the technical and business levels, mapping connections between technological components, roles, and actors. The method includes two layers: a static technical architecture defining components and interfaces and a dynamic industry architecture outlining roles and business interactions. Different industry architectures can be derived from the technical layer (Casey et al., 2010; Heikkinen et al., 2010). Unlike enterprise-focused methods, VNC enables industry-level analysis and integrates technical and business architectures into one framework (Borenius et al., 2023; Heikkinen et al., 2010).

3.4. Data collection

The DCF model was based on a framework derived from existing public safety mobile broadband projects (Savunen et al., 2023), encompassing market, service, and technology definitions; business models (including industrial architecture); and revenue and cost elements. For the sensitivity analysis, the business risk scenarios from Savunen et al. (2024) were used as a reference (see Section 2.4).

Revenue and cost data were primarily derived from data collected from public sources and validated through expert interviews. Six senior experts from Telia Finland, Erillisverkot, Airbus Defence and Space, and Spinverse participated, confirming the accuracy of the publicly sourced data and providing additional insights. Telia Finland is part of a Swedish telecom operator active in the Nordic and Baltic regions; Erillisverkot, a Finnish state-owned company, focuses on critical communications; Airbus Defence and Space, a division of Airbus Group, conducts global public safety business; and Spinverse, a Finnish business consulting firm. The results of the DCF model were further validated through expert discussions.

To collect MNO data, five reference MNOs were defined, two of which are involved in existing public safety projects: Elisa (Virve 2 in Finland) and BT Group/EE (ESN in the United Kingdom). The MNOs' annual reports and financial statements were the sources of key business figures (BT Group, 2024; DNA, 2024a; Elisa, 2024a; Telia Company, 2024a; Vodafone Group, 2024). These were supplemented with data from other public sources.

The FCC's (2010) and Sitowise's (2020) reports with complementary expert interviews were the sources used to estimate the costs of extending RAN coverage and improving network resilience. The FCC's (2010) report served as a valuable reference, as it represents one of the studies conducted prior to the establishment of the FirstNet Authority in 2012 (FirstNet Authority, 2021). The pricing of public safety services was estimated based on FirstNet's (2024a; 2024b) prices and expert interviews. Table 1 summarises the data sources.

4. Results

4.1. VNC of multi-actor and single-actor business models

Figs. 2 and 3 illustrate the VNC of the multi-actor and single-actor business models (see Section 2.3 and Fig. 1), focusing on the technical and industrial architecture of the service provision layer. Technical architecture is based on 3rd Generation Partnership Project (3GPP) specifications and following 3GPP-defined interfaces between elements, where applicable. Upstream actors, such as device vendors and network and solution providers, were excluded from this analysis.

The primary difference between these business models is the distribution of responsibilities for RAN, core network, and MCS application services. In the multi-actor business model, these services are shared between the MNO and the public safety service operator, with the MNO providing only shared RAN services. This setup, in which RAN is shared, is referred to as the multi-operator core network (MOCN) configuration (3rd Generation Partnership Project, 2024). In the single-actor business model, the MNO handles all three services. The single-actor model, used in FirstNet in the United States, gives the MNO more control over public safety services, while in the multi-actor model used in European projects, end-to-end services and customer interface are typically managed by a state-owned public safety operator. This difference reflects different political and regulatory approaches in the European Union and the United States (Ahearn, 2008; Fukuyama & Grotto, 2020).

The differences in business models also affect other actors beyond the MNO and the public safety operator. Under the multi-actor model, the GA handles two separate procurement processes for the public safety service operator and MNO and must ensure seamless end-to-end service delivery. In contrast, the single-actor model simplifies the GA's role with a single procurement process and one operational partner.

In practice, project configurations may differ from the described models. For example, in the Virve 2 project, Erillisverkot acts as both the public safety service operator and the GA, managing MNO procurement, overseeing the MNO contract execution, and serving as the single point of contact for user organisations. The payment model by which the MNO receives the service fee for the connectivity

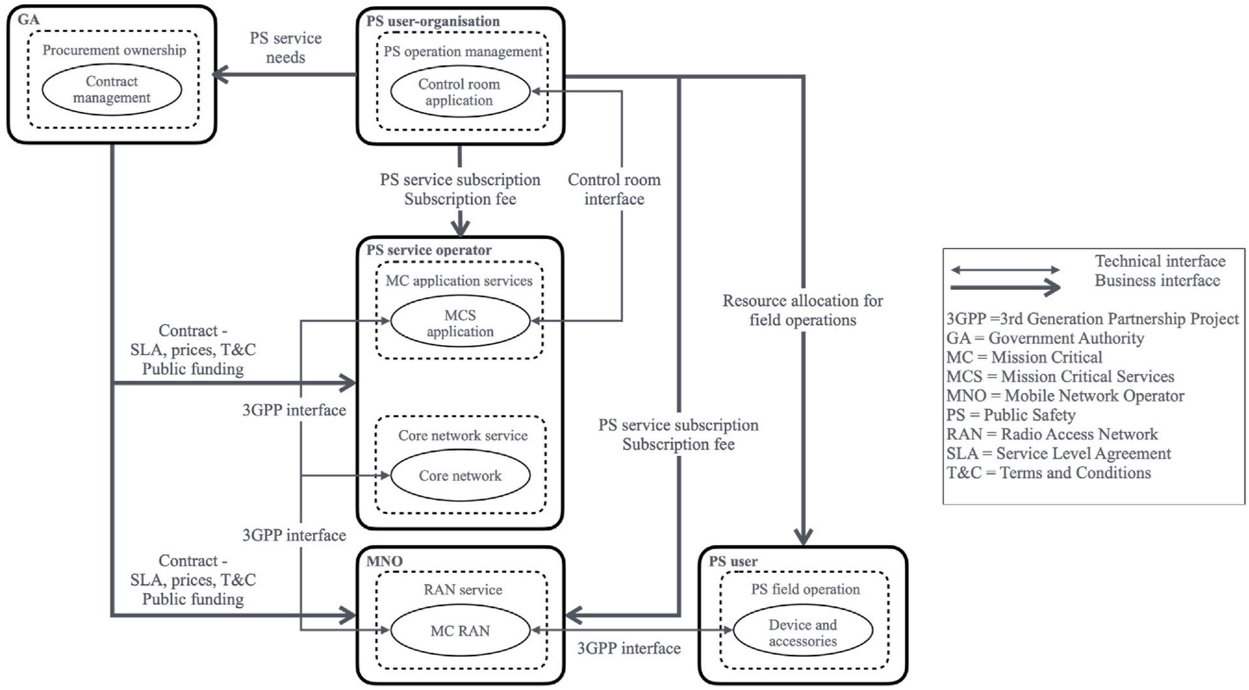


Fig. 2. VNC of the multi-actor business model.

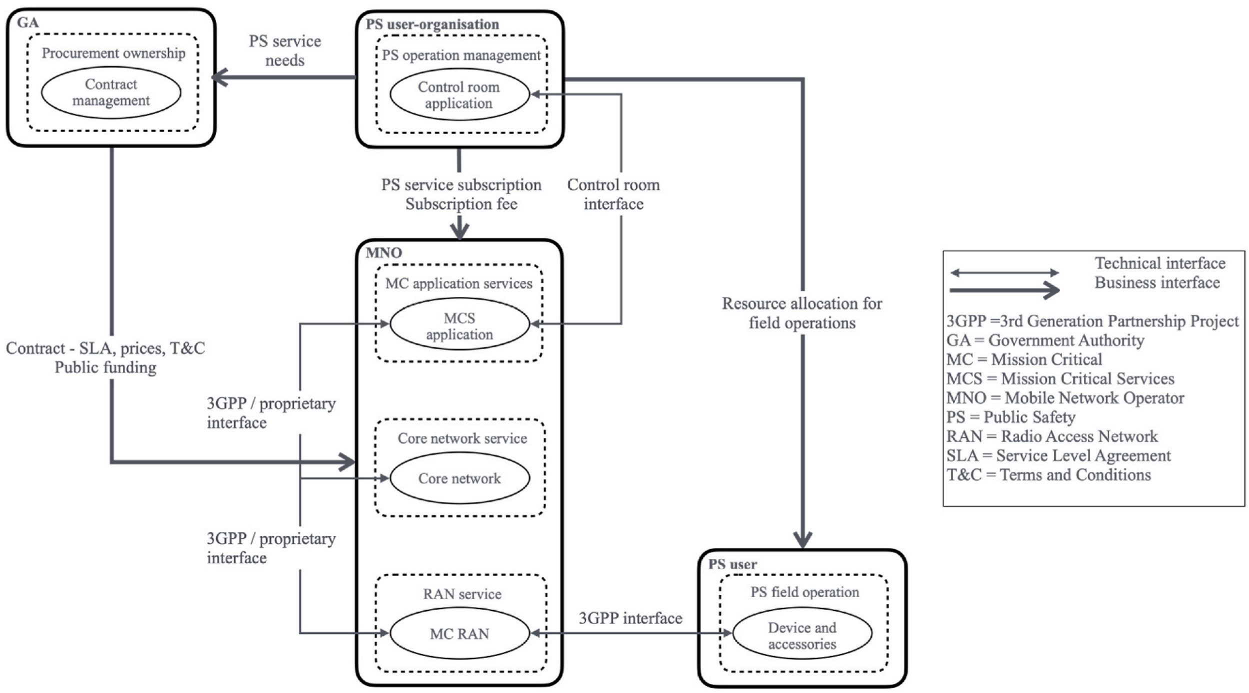


Fig. 3. VNC of the single-actor business model.

service under the multi-actor model can also differ from the outlined model. The service fee may come from the GA or the public safety service operator rather than the user organisation and may be included in the project's public funding or priced as a wholesale service (Savunen et al., 2023).

4.2. DCF model

4.2.1. Structure of the DCF model

The DCF model describes the MNO's business within a public safety mobile broadband project, with the aim of analysing the factors that influence the MNO's profitability. The data for the model were collected from various public sources and expert interviews, as described in Section 3.4 and Table 1.

Fig. 4 illustrates the structure of the DCF model according to Smura's (2012) presentation logic. The model contains separate cash flow elements for revenue, operating expenditures (OPEX), and capital expenditures (CAPEX), with the latter representing investments. A detailed list of revenue and cost items is provided in Tables A.1 and A.2 in Appendix A. The cost element *cost of using existing RAN* includes all expenses associated with the existing RAN, including spectrum costs, as no additional spectrum is allocated for public safety services in our case. The DCF model excludes cost items for air-to-ground, maritime, and railroad coverage, as well as for control room integration. While these may be part of certain existing projects, they can vary significantly across projects.

The DCF model includes all elements of the four scenarios detailed in Section 4.2.5. While most cash flow elements are common to both business models, some revenue and cost elements are specific to the single-actor model, as indicated by an asterisk in Fig. 4. The distinction between sparsely and densely populated countries lies in the population density parameters presented in Table 5.

The model evaluates the financial profitability of the project for the MNO using the following criteria: NPV, IRR, payback period, and ARPU. It also includes a sensitivity analysis, and the various sensitivity analysis parameters evaluated are underscored in Fig. 4. The key parameters of the model are described in Sections 4.2.2–4.2.5.

4.2.2. Market

The market area of the project reflected in the DCF model is assumed to be a European country with 30 million inhabitants. Other figures represent typical averages in European countries (Table 2).

4.2.3. Project

The DCF model describes a project based on a contract between an MNO and a GA aiming to provide mobile broadband services to public safety users, including police forces, fire and rescue services, paramedics, and other critical organisations supporting public safety. The services rely on the MNO's 4G/5G network, enhanced with coverage extension and network hardening to meet MC requirements. The country has 225,000 potential public safety users (Table 2). The contract spans 10 years, with 3 years dedicated to network design and building, followed by 7 years for operation and maintenance. The project supports a transition from narrowband to broadband technologies, which can begin at the start of the operational phase.

The payment model defines how the MNO is compensated for project deliveries. The DCF model includes two payment models. In the first model, the MNO receives public funding[2] from the GA at a fixed price for RAN coverage extension, network resilience and security improvements, and maintenance. Payments are based on milestones during the building phase and annual payments during the maintenance phase. Additionally, public funding covers the cost of next-generation technology upgrades for network extensions. The second payment model – subscription-based – covers services like MC connectivity, MCS and public safety applications, and devices with accessories. The MNO receives subscription fees for these services, meaning that the revenue is directly tied to the number of users. Other payment models may also be applied in real-world projects, as discussed in Section 4.1.

4.2.4. MNO

The MNO business figures in Table 3 follow the key business figures of five reference MNOs: BT Group/EE, DNA, Elisa, Telia Company, and Vodafone Group. The data sources are detailed in Table 1.

The share of the public safety sector in the MNO's entire subscriber base is only 1.6 %, which reflects the relatively small number of public safety personnel compared to the MNO's broader consumer and enterprise segments.

The project's two distinct payment models enable separate profit targets for service components. Given the enhanced RAN provides the MNO with a competitive advantage in the market, and recognising the importance of a competitive bidding price, a reduced profit target for RAN enhancements is justified. However, stringent service requirements necessitate the inclusion of a risk premium to safeguard profitability. To balance these objectives, the DCF model employs a cost-plus pricing method with a 25 % markup. For subscriber-based services, the MNO's profit targets align with those of its standard mobile communications business. The price level follows the European mobile communications market, including a premium that accounts for specific MC requirements. FirstNet (2024a, 2024b) pricing examples were also considered.

4.2.5. Scenarios of the DCF model

The DCF model addresses public safety mobile broadband projects through four scenarios created by combining two attributes with two values each (Fig. 5). The first attribute of the scenario is the business model, which includes both multi-actor and single-actor models (see Section 2.3, Fig. 1). VNCs for these models are discussed in Section 4.1 and shown in Figs. 2 and 3.

The fee-based services provided by the MNO vary depending on the business model, as shown in Table 4. The fundamental service is connectivity – essentially a mobile broadband service – that serves as the foundation for MCS and public safety applications.

[2] In this study, the term "public funding" is used to refer to the payment that the MNO receives from the GA for RAN extension, network hardening, and maintenance. Other terms – such as "availability payment", which is commonly used in PPP projects – could also apply here.

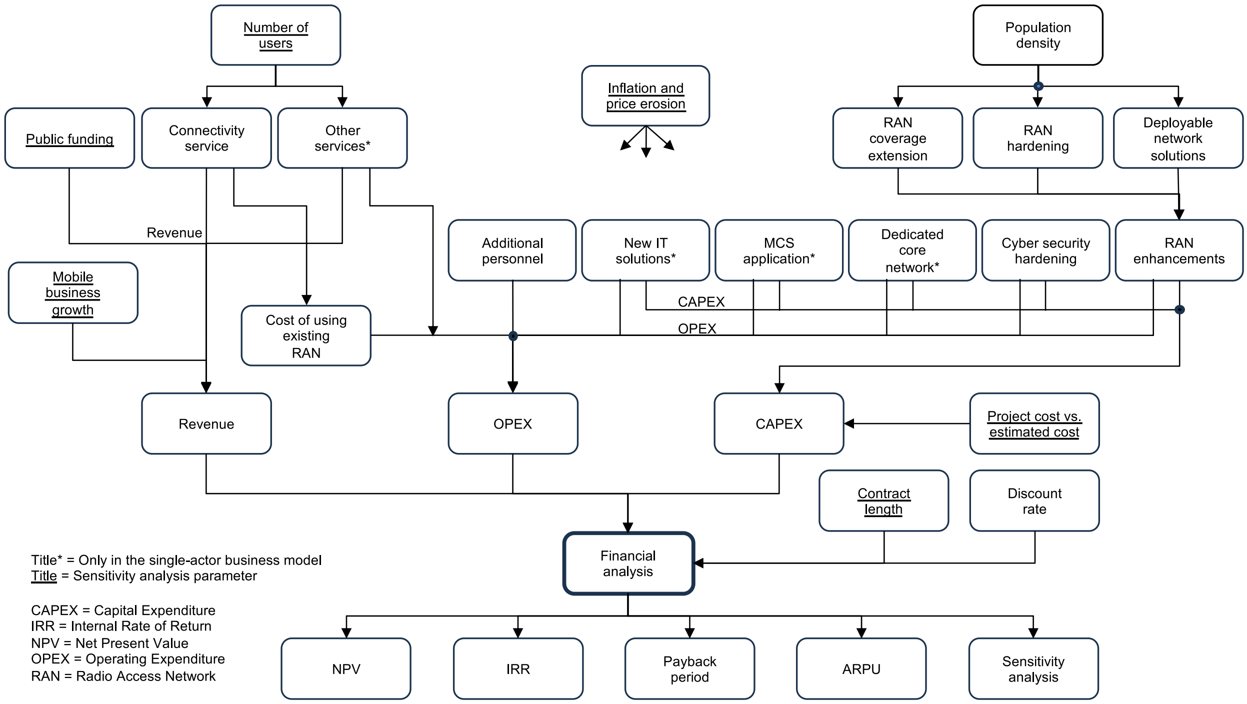


Fig. 4. DCF model structure.

Table 2
Project market.

Item	Value
Population	30 million
Number of mobile subscriptions	45 million
Number of public safety users [a]	225,000
Corporate income tax rate	21.5 %
Inflation rate	2.0 %
Price erosion of wireless telephone services	−1.0 %

[a] Services are also used by other critical organisations (e.g., government agencies supporting public safety).

Table 3
MNO's business figures.

Figure	Value
Market share of the mobile market	31.5 %
Number of mobile subscribers	14,175,000
Proportion of PS users in the country vs. MNO's mobile subscribers	1.6 %
ARPU, postpaid customers	21.84 EUR
WACC	6.6 %
EBITDA%	35.1 %
Personnel cost per employee per year	67,852 EUR
Number of existing radio sites	17,000

PS = Public safety; ARPU = Average revenue per user; WACC = Weighted average cost of capital; EBITDA = Earnings before interest, taxes, depreciation and amortisation.

Connectivity is classified as an MC service, providing greater reliability than consumer-grade services through extended radio coverage, improved network resilience, and hardened cybersecurity. Public safety services typically require bitrates starting from megabits per second per user to support video streaming and other data-intensive applications (Peltola & Hämmäinen, 2018). The absolute minimum requirement applies to MCPTT with voice-only communication, which can function with just tens of kilobits per second per user. In large public safety operations with a high number of first responders, the required capacity must be scaled by adding together the capacity needs of individual users. As a result, the total radio cell capacity requirement can become substantial

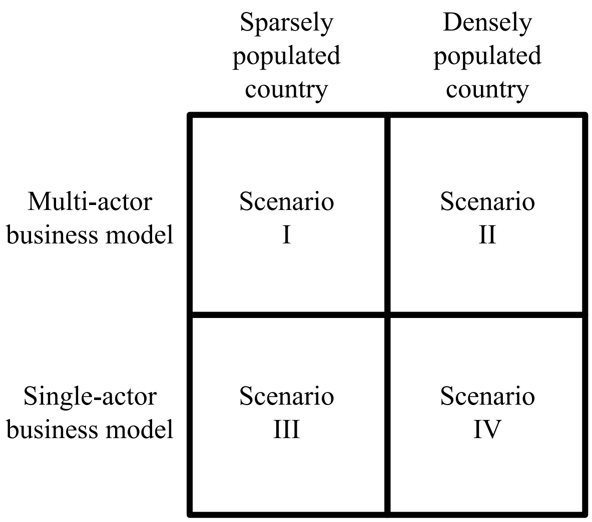


Fig. 5. Four scenarios of the DCF model.

Table 4
Fee-based MNO services in multi-actor and single-actor models.

Service	Multi-actor business model	Single-actor business model
MC RAN connectivity service	✔	
MC end-to-end connectivity service		✔
MCS and public safety applications		✔
Devices and accessories		✔

MC = Mission-critical; RAN = Radio access network; MCS = Mission-critical services.

(Santiago et al., 2024).

Connectivity services differ depending on the business model. In the multi-actor model, the MNO provides an MC RAN connectivity service exclusively for the RAN, whereas in the single-actor model, the MNO delivers an MC end-to-end connectivity service, covering both the RAN and all upper-layer services. Further information on public safety mobile broadband services is available in Peltola and Hämmäinen (2018) and Savunen et al. (2023).

The other defining attribute of the scenario is the population density of the country, including two values: sparsely and densely populated countries. Population density is a key factor in MNO network design. In MNO networks, urban areas with high population density require substantial capacity, and MNOs use higher-frequency bands, a mix of macro and small cells, and multiple bands. This improves RAN redundancy and resilience by minimising the impact of outages, as devices can connect to alternative cells or bands (ElNashar et al., 2014). Conversely, in rural areas, coverage takes priority over capacity; therefore, macro cells with lower frequency bands are used. These cells cover larger areas, but outages have a broader impact due to limited overlapping coverage. Additionally, rural areas are more vulnerable to power outages caused by natural disasters (e.g., storms and wildfires) due to the lack of sufficient redundancies in rural energy networks (Onnettomuustutkintakeskus, 2010).

Population density also affects the investments needed for MNO RAN enhancements to meet MC requirements. Sparsely populated countries require broader network coverage extensions than densely populated ones, driving higher costs. Research indicates that NPV per radio cell increases with population density, making rural deployments less profitable (Hallahan & Peha, 2011). Moreover, to ensure high service availability, sparsely populated areas face greater demands for both resilience improvements, such as additional backup power and duplicated transmission links, and deployable network solutions.

Table 5 outlines the parameters defining the requirements for RAN extension and hardening. These parameters vary based on population density, differing between densely and sparsely populated countries. Parameters specify the proportion of new radio sites relative to existing ones, the distribution of new sites between suburban and rural areas, the percentage of existing sites that are hardened by implementing redundant transmission links and additional backup power for energy supply disruptions, and the required number of deployable network solutions.

These options enable the analysis of RAN investment impacts on the MNO's business. While a specific figure for typical RAN investments cannot be defined for the DCF model due to the manifold factors that influence investment amounts in real-life projects, the two population density values enable an analysis of the effects of RAN investment.

The first row of Table 5 defines the increase in radio sites versus existing sites, following the available data from existing projects. For the ESN project in the United Kingdom, the proportion of new radio sites – including those under the responsibility of EE and the Home Office – is 4.8 % (Harrap, 2022; National Audit Office, 2023). In the United States, an FCC (2010) report estimates the proportion of new radio sites to be 7.7 %.

4.3. Baseline model results

A baseline model was developed to evaluate the MNO's financial profitability in the project, representing the most likely outcome. This model also serves as the starting point for the sensitivity analysis. Table 6 outlines the key parameters of the baseline model, including descriptions, values, and rationales, which are also used in the sensitivity analysis (Section 4.4).

Fig. 6 illustrates the baseline model's profitability indicators: NPV, IRR, and payback period. Scenario I (Fig. 4) showed a negative NPV, with the other scenarios showing positive NPVs, making them potential investments for the MNO. Single-actor scenarios have 148 million EUR higher NPVs than their multi-actor counterparts due to additional services and revenue. The multi-actor model limits the MNO to providing only MC RAN connectivity service.

Densely populated scenarios yield NPVs over 78 million EUR higher than sparsely populated ones due to lower network investments. With public funding below 100 %, the MNO bears part of the RAN enhancement costs; this dynamic has a greater negative impact on NPV in scenarios with higher RAN costs. The IRR and payback periods align with NPV, with higher NPVs leading to higher IRR and faster payback.

In summary, the least profitable scenario is the multi-actor model in a sparsely populated country, where 85 % public funding makes the scenario's NPV negative and the IRR below the MNO's weighted average cost of capital (WACC). This makes the project unprofitable. In contrast, the single-actor model in a densely populated country is the most attractive opportunity, with a healthy NPV, an IRR well above WACC, and a payback period under 7 years.

Fig. 7 illustrates the discounted revenue of the baseline model, categorised into public funding, connectivity services, and other services, according to their respective shares of total revenue. Other services include MCS and public safety applications, devices, and accessories. Public funding is a significant source of revenue, especially in sparsely populated scenarios. However, this funding is allocated to network investment and maintenance, so it does not directly drive profits. In single-actor scenarios, other services contribute significantly, and connectivity revenue is higher than in multi-actor scenarios, where connectivity represents a relatively small source of revenue.

Fig. 8 presents the discounted ARPU figures for the baseline model. ARPU figures are divided into connectivity services and other services based on the share they represent on ARPU; other services include MCS and public safety applications, devices, and accessories. Services vary based on the business model; see Table 4 for details. These figures take price erosion, discount factor, and changes in the number of users over time into account, resulting in values lower than the initial (starting year) values: 21.84 EUR for the MNO's mobile postpaid services, 9.83 EUR for connectivity services in Scenarios I and II, and 26.20 EUR for connectivity services in Scenarios III and IV. The ARPU for other services reflects a weighted combination of multiple services.

Under the multi-actor model in Scenarios I and II, the ARPU is lower than both the MNO's mobile postpaid ARPU and the ARPU in the single-actor model in Scenarios III and IV. This is because the MNO provides only MC RAN connectivity, resulting in a more limited scope of services. In contrast, the ARPU in the single-actor scenarios is four times that of the MNO's standard postpaid ARPU due to the wider range of services.

Public funding is excluded from the ARPU, as it is not tied to subscribed services. Without public funding, subscription fees would need to increase by 94.71 EUR per month in a sparsely populated country and by 40.02 EUR per month in a densely populated country, significantly increasing connectivity service prices and challenging the service's feasibility for public safety users.

4.4. Sensitivity analysis

A univariate sensitivity analysis assessed the impact of key parameters on project profitability. This analysis offers insight into the uncertainties and risks – as well as potential additional business opportunities – presented by the project. Baseline parameters from Table 6 were varied for the sensitivity analysis, as shown in Table 7. Fig. 9 shows the sensitivity analysis results, illustrating the variation of the NPV as vertical floating bars for each scenario. Diamond markers indicate baseline values.

The sensitivity analysis highlights that the project's profitability is sensitive to public funding. A slight decrease can make the project unprofitable, while higher funding greatly improves profitability. The public funding needed for an NPV of 0 is 89.9 % in Scenario I, 83.5 % in Scenario II, 79.4 % in Scenario III, and 58.8 % in Scenario IV. For an NPV of 200 million EUR, funding levels of 104.0 %, 116.9 %, 93.5 %, and 92.2 % are required, respectively.

Project profitability is also highly sensitive to project cost variations. A 20 % cost increase relative to the estimated costs makes all

Table 5
RAN requirements for a densely populated country versus a sparsely populated country.

Requirement	Densely populated country	Sparsely populated country
Increase in radio sites vs. existing sites	5 %	9 %
Share of additional radio sites in suburban areas	80 %	50 %
Share of additional radio sites in rural areas	20 %	50 %
Share of existing sites with duplicated links	10 %	25 %
Share of existing sites with additional backup power supply	10 %	25 %
Number of deployable network solutions	25	100

Table 6
Baseline model parameters.

Parameter	Description	Baseline value and reasoning
Contract length	Contract period in years, including network building, operation and maintenance phases.	**Baseline: 10 years**; a typical contract length in European projects.
Inflation	Price changes per year.	**Baseline: 2.0 %**; the long-term inflation target of the European Central Bank and the U.S. Federal Reserve.
Mobile business growth	The impact on the MNO's mobile business can be positive (increase in mobile business market share) or negative (decrease in market share).	**Baseline: no growth**.
Number of users	The number of users compared to the number of potential public safety users in the country.	**Baseline: 100 %**; all potential public safety users use MNO's services.
Project cost	The actual versus the estimated cost of the network extension, hardening and maintenance.	**Baseline: 110 %**; the costs exceed the plans by 10 % due to unforeseen expenses incurred during the implementation of the radio coverage extension and network hardening.
Public funding	The payment that the MNO receives for building and maintaining the network's extension and hardening. For example, 100 % funding means that all MNO costs, including the 25 % risk premium, are completely reimbursed.	**Baseline: 85 % funding**; MNO does not receive 100 % funding due to competition; one could argue that the MNO will benefit from the network enhancements in its other operations.

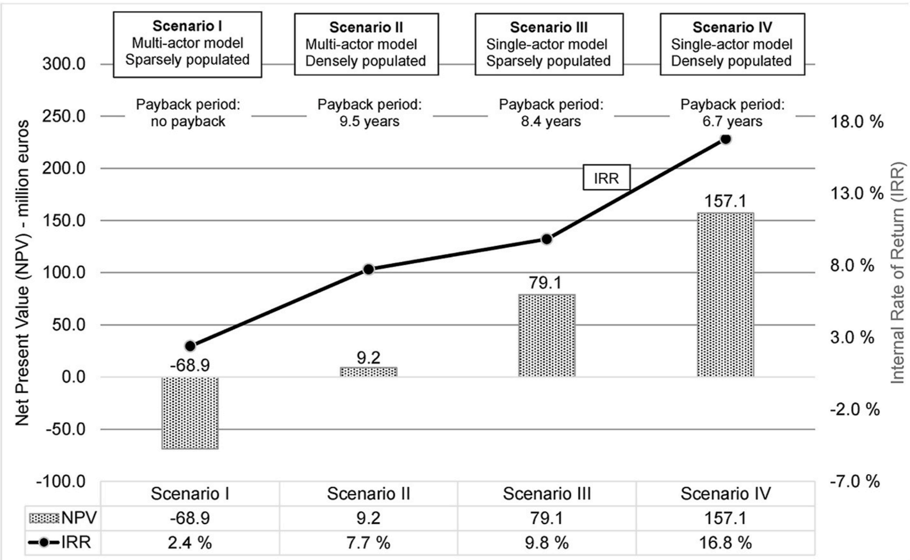


Fig. 6. NPV, IRR, and payback period for the baseline model.

scenarios except Scenario IV unprofitable. Conversely, strict cost management, resulting in costs 20 % lower than estimated, would greatly improve profitability across all scenarios.

The financial impact of public safety operations on the MNO's standard mobile business can be considerable, presenting both opportunities and risks. The parameter under consideration is mobile business growth: An increase of 2.0 percentage points in market share would increase NPV by 384 million EUR, while a corresponding decrease of 2.0 percentage points would lead to an equivalent reduction in NPV. Notably, however, large changes in market share are relatively unlikely, with smaller fluctuations being more common.

The discussed parameters – public funding, project costs, and mobile business growth – significantly affect profitability, presenting both risks and opportunities. While other parameters – contract length, number of users, and inflation – also impact profitability, their effects are less pronounced. Contract length increases profitability, especially in the single-actor model in Scenarios III and IV. Similarly, an increase in the number of users enhances profitability, particularly in the single-actor model, due to the wider range of services and higher ARPU that the MNO provides. Conversely, if the project does not fully engage all potential public safety users, profitability will fall short of expectations.

The final sensitivity analysis parameter, inflation, decreases profitability in Scenarios III and IV, as expected, but increases profitability in Scenarios I and II. This is due to the DCF model, in which public funding is the dominant revenue source in the multi-actor business model. Public funding is tied to RAN-related costs, which rise with inflation, while RAN investment depreciation remains unaffected.

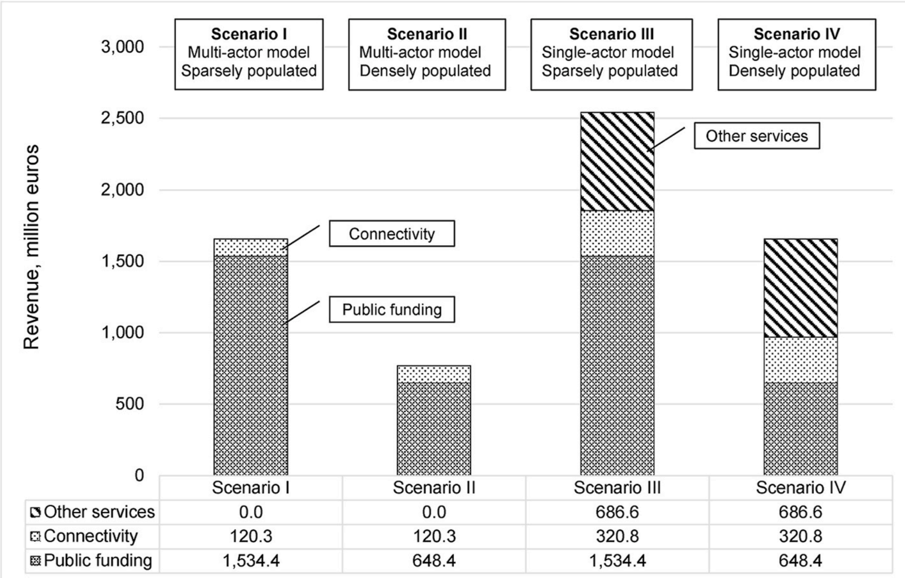


Fig. 7. Discounted revenue of the baseline model.

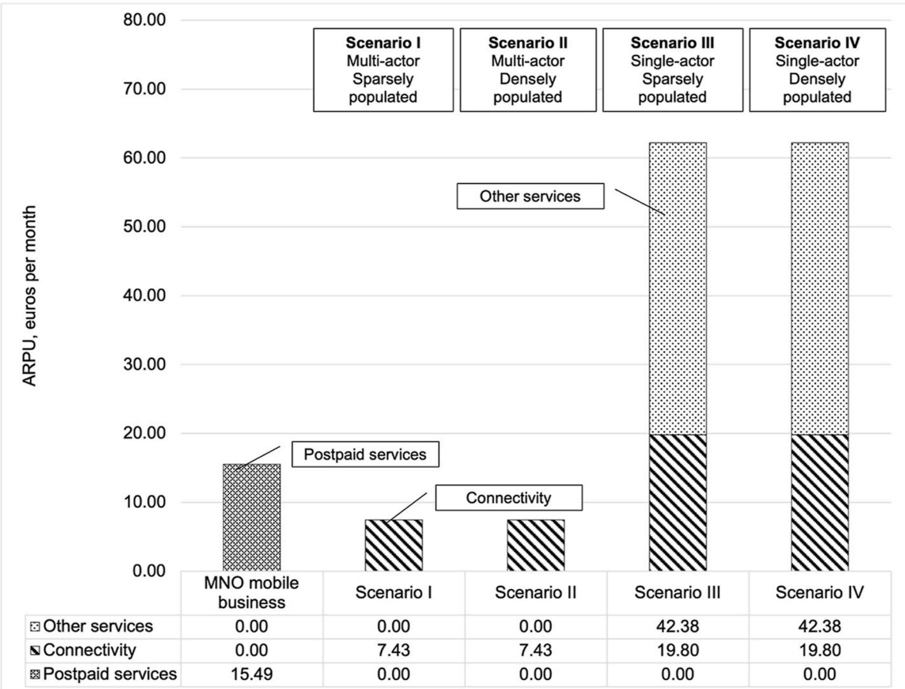


Fig. 8. Discounted ARPU figures of the baseline model (price erosion included).

4.5. Implications for MNO's financial figures

Assessing the financial implications of a public safety project in relation to an MNO's standard mobile business is challenging due to the lack of a single indicator. While the DCF model provides the project's NPV, comparing it with the MNO's mobile business is difficult due to the unknown MNO's NPV. Estimating this would require the identification of several unknown MNO-specific parameters, potentially compromising the accuracy and generality of the estimation. Therefore, it is essential to use multiple indicators to analyse the overall financial impact: 1) number of new users, 2) revenue growth, 3) ARPU comparison, and 4) impact on the MNO's mobile business market share.

Table 7
Parameter variation in univariate sensitivity analysis.

Parameter	Univariate sensitivity analysis
Contract length	Minimum: 7 years Maximum: 13 years
Inflation	Minimum: 0 % Maximum: 6 %
Mobile business growth	Minimum: 2.0 percentage point decrease in market share (from 31.5 % to 29.5 %) Maximum: 2.0 percentage point increase in market share (from 31.5 % to 33.5 %)
Number of users	Minimum: 70 % Maximum: 130 %
Project cost	Minimum: 80 % Maximum: 140 %
Public funding	Minimum: 55 % Maximum: 115 %

The increase in the number of users is small, with only a 1.6 % increase in the MNO's mobile business figure. This aligns with existing public safety projects (Savunen et al., 2023). This modest growth does not justify substantial strategic investments. The revenue impact is more significant, but it is primarily driven by public funding for RAN enhancements, which does not contribute to profit. In the multi-actor scenarios, additional revenue from connectivity services is just 0.4 % of the MNO's mobile business revenue, while the single-actor scenarios generate 3.5 % additional revenue from connectivity and other services.

The ARPU figures align with the revenue impact findings. In the multi-actor model, the ARPU for connectivity services is about half of the MNO's postpaid mobile business ARPU. In contrast, the single-actor model's ARPU is about three times higher than the MNO's postpaid ARPU.

An increase in the MNO's market share could result in a substantial increase in revenue; a market share increase of 2.0 percentage points equates to a 6.3 % boost in the MNO's revenue. However, there is also a risk of market share decline. In addition, a market share increase of 2.0 percentage points is substantial, and its feasibility should be assessed in relation to specific market conditions. For instance, are there underserved areas due to inadequate radio coverage?

In conclusion, the impact of the public safety project on the MNO's financial figures is relatively modest. While the single-actor scenarios show better figures, they remain relatively low. Potential market share growth could substantially boost the MNO's revenue, but its feasibility depends on market conditions. Improved RAN coverage and service quality could create opportunities in new vertical markets, such as energy network communications driven by renewable energy growth (Borenius et al., 2023).

4.6. Model validation

To validate the financial model, in addition to expert validation, the researchers used a comparative approach, assessing the results generated by the DCF model against financial data from an actual public safety project. The United Kingdom's ESN project was selected based on its compatibility with one of the model's scenarios, the availability of public financial data, and data not used in the development of the DCF model.

The ESN project, following the multi-actor business model, involves BT Group/EE as the MNO and another actor providing MCS and public safety services. EE was awarded the contract in December 2015, renegotiated in 2019, and extended through December 2024, with a revised value of 895.7 million GBP (1.047 billion EUR)[3] for mobile services, coverage extensions, and system improvements to ensure high service availability (TED, 2019).

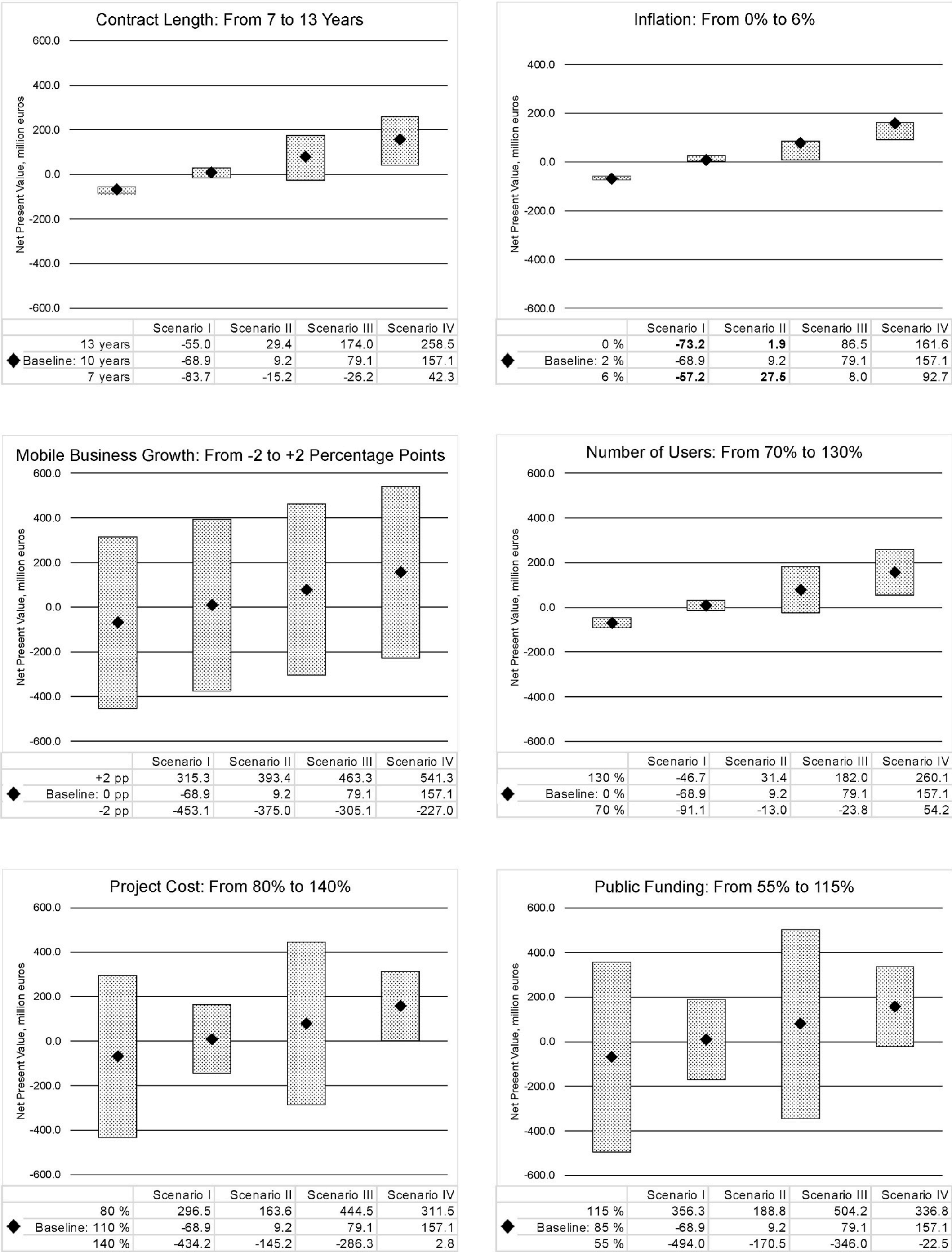
EE's contract included the implementation of 675 new radio sites to extend the radio coverage area (National Audit Office, 2023). Using this number as the parameter for new radio sites in the DCF model, along with the 9-year contract period and Scenario II, the model estimated a cumulative nominal value of 897.0 million EUR for the MNO's revenue over the contract period. This represents 85.7 % of EE's contract value, demonstrating that the DCF model's results align closely with the actual value of EE's contract, especially considering that the content of the ESN project differs somewhat from the assumptions of the DCF model.

5. Discussion

5.1. Research contribution

Building on prior qualitative research on using MNO networks for public safety services, an MNO's role in public safety projects, and the associated business risks, this study established a foundation for a quantitative analysis of MNOs' public safety business. This advances the field by offering a financial model to evaluate MNOs' profitability factors in public safety projects. While the results are intrinsically valuable, the DCF model and publicly sourced data serve as significant contributions for future research.

[3] European Central Bank currency rates, March 5, 2024.



Contract Length	Scenario I	Scenario II	Scenario III	Scenario IV
13 years	-55.0	29.4	174.0	258.5
◆ Baseline: 10 years	-68.9	9.2	79.1	157.1
7 years	-83.7	-15.2	-26.2	42.3

Inflation	Scenario I	Scenario II	Scenario III	Scenario IV
0 %	**-73.2**	**1.9**	86.5	161.6
◆ Baseline: 2 %	-68.9	9.2	79.1	157.1
6 %	**-57.2**	**27.5**	8.0	92.7

Mobile Business Growth	Scenario I	Scenario II	Scenario III	Scenario IV
+2 pp	315.3	393.4	463.3	541.3
◆ Baseline: 0 pp	-68.9	9.2	79.1	157.1
-2 pp	-453.1	-375.0	-305.1	-227.0

Number of Users	Scenario I	Scenario II	Scenario III	Scenario IV
130 %	-46.7	31.4	182.0	260.1
◆ Baseline: 0 %	-68.9	9.2	79.1	157.1
70 %	-91.1	-13.0	-23.8	54.2

Project Cost	Scenario I	Scenario II	Scenario III	Scenario IV
80 %	296.5	163.6	444.5	311.5
◆ Baseline: 110 %	-68.9	9.2	79.1	157.1
140 %	-434.2	-145.2	-286.3	2.8

Public Funding	Scenario I	Scenario II	Scenario III	Scenario IV
115 %	356.3	188.8	504.2	336.8
◆ Baseline: 85 %	-68.9	9.2	79.1	157.1
55 %	-494.0	-170.5	-346.0	-22.5

Fig. 9. Results of univariate sensitivity analysis – Scenario I: Multi-actor, sparsely populated; Scenario II: Multi-actor, densely populated; Scenario III: Single-actor, sparsely populated; Scenario IV: Single-actor, densely populated.

5.2. *Policy considerations*

Public safety mobile broadband projects require significant investments, leading to long-term contracts, typically around 10 years in Europe. A robust legislative and regulatory framework is essential to defining roles and expectations, thereby reducing risks and encouraging MNOs to engage in the public safety business. Without this, regulatory changes after the contract is signed could pose risks to MNOs (Howell & Sadowski, 2018).

Examples of legislation governing public safety services include the Middle Class Tax Relief and Job Creation Act (2012) in the

United States, which established the FirstNet Authority to create a network for first responders. Later, a 25-year PPP contract granted AT&T the right to deliver FirstNet services. Similarly, the Act on the Operation of the Government Security Network (2019) in Finland grants Erillisverkot, the government service operator of Virve 2, the exclusive right to offer MC mobile communications services to public safety organisations. As a result, Elisa, the MNO behind Virve 2 RAN services, faces no competition in public safety MC mobile communications during the contract period.

This study finds that the single-actor business model used in the United States provides MNOs with stronger financial performance and a more favourable position in the value chain compared to the multi-actor model used in Europe. Key financial metrics – NPV, IRR, payback period, and ARPU – are significantly better in the single-actor business model than in the multi-actor model. This advantage is due to the wider range of services enabled by the single-actor model. In single-actor scenarios, ARPU is three times higher than the MNO's standard postpaid ARPU due to the large service portfolio. In contrast, under the multi-actor model, ARPU falls below the MNO's postpaid ARPU, as the MNO's role is limited to providing only RAN services (for ARPU, see Fig. 8). Additionally, in the single-actor model, the MNO maintains direct control over the public safety customer interface, facilitating additional service sales and innovation opportunities.

In addition to the study's findings, the status of current projects also suggests that single-actor projects may yield better results and involve fewer risks compared to their multi-actor counterparts. For instance, FirstNet is fully operational with a large customer base (FirstNet, n.d.), while European multi-actor projects are still in the implementation phase, with service integration across multiple vendors identified as a significant challenge (National Audit Office, 2023). However, it is important to acknowledge that the business model is just one contributing factor, and there are other key differences between European projects and FirstNet. European projects prioritise a rapid transition from narrowband to broadband, while FirstNet aims to provide value-added data services to first responders, and narrowband services will be used alongside broadband technology.

These findings raise an important question regarding the regulatory position of the single-actor business model in Europe. In the European Union, while no specific directive explicitly prohibits an MNO from managing an end-to-end public safety service, competition policies make it challenging for a single MNO to independently operate public safety services or enter into very long contracts, as seen with AT&T in the United States. It is also important to note that the public safety sector is a relatively small niche market compared to MNOs' standard market, which may require distinct regulatory requirements. Especially in Europe, national public safety projects tend to be small in scale, serving populations in the range of millions to tens of millions compared to the hundreds of millions of residents served in the United States. Consequently, the European Union may need to reconsider its regulatory framework to allow more flexibility, especially in scenarios where a single-actor model could demonstrably deliver better outcomes for public safety services.

MNO services are vital for many societal functions, with growing demands for their availability, reliability, and security. This raises an important question regarding the allocation of costs for enhancing the service levels of MNO networks: Should the responsibility for these costs rest solely on a specific user segment, such as public safety organisations, or should regulations be revised to establish higher baseline requirements for network availability, resilience, and security? For example, during severe storms in Finland in 2010, prolonged power outages caused 1050 mobile network radio site outages at the peak of the crisis (Onnettomuustutkintakeskus, 2010). Increased regulatory requirements, such as longer power backup durations, could mitigate such issues and benefit all users, including critical organisations.

5.3. Recommendations for MNOs

Public funding ***and project costs:*** RAN building and maintenance costs are the largest expenditure for an MNO in public safety projects and cannot be covered solely by a reasonable margin from services provided to public safety users, necessitating public funding. This study found that public funding to achieve zero NPV ranges from 59 % to 90 % of the total costs for RAN enhancement and maintenance, depending on the scenario. Achieving a reasonably positive NPV would require a higher level of funding. Public funding in this study refers to the payments the MNO receives for building and maintaining RAN coverage extension and network hardening; see Section 4.2.3 and Table 6 for details. Additionally, it is critical to control RAN building and maintenance costs, as underestimating them during contract negotiations can severely jeopardize profitability. The project's greatest risk arises from a combination of insufficient public funding and higher-than-expected RAN enhancement costs, making careful contract negotiations and project planning essential.

Another option for public funding is to cover all MNO costs through subscription fees, although this is challenging due to substantially higher service fees – an increase of 94.71 EUR per month in sparsely populated countries and 40.02 EUR per month in densely populated countries – which would probably not be acceptable. Higher fees could strain public safety budgets and reduce the number of users. In the worst case scenario, publicly funded network investments could fail to achieve their full value due to limited user adoption.

Business model: In the multi-actor business model, the MNO provides only MC RAN services, while in the single-actor model, it manages the entire range of public safety services. Financial metrics and value chain position are stronger in the single-actor model, enabling cross-selling, innovation, and revenue growth. Financially, the single-actor model is preferable and should be the MNO's choice, unless strategic reasons favour the multi-actor model. Where possible, the MNO should advocate for its preferred business model prior to procurement or during contract negotiations.

Mobile business growth: As the MNO improves RAN coverage and resilience, it gains a competitive advantage that can grow the MNO's market share and expand its mobile business. The financial benefits of this growth can be significant, potentially multiplying the NPV of the public safety project. To maximise business benefits, the MNO should focus its marketing efforts on the customer segments that are most likely to benefit from enhanced network performance, such as underserved consumers and enterprises in areas with improved coverage.

Sharing the MNO's RAN with public safety organisations may degrade service quality for consumers and enterprises. This decline could drive regular customers to competitors and lead to a loss of market share. To mitigate this negative impact, the MNO must maintain stable service quality for its regular customers; see Savunen et al. (2024) for recommended technical measures.

Contract: According to Savunen et al. (2024), a long contract period is justified by substantial network investments, the long repayment time they require, and further innovation opportunities. The results of this study support long contract periods, indicating that they positively influence a project's NPV. Therefore, the MNO's strategy in contract negotiations should centre on defending a long contract period. National legislation may limit the length of public procurements. For instance, the European Union public procurement directive encourages public authorities to avoid excessively long contracts that could hinder competition (European Union, 2014).

5.4. Suggestions for GAs

The first goal of a GA in procuring public safety services is to demonstrate to MNOs that the project represents a profitable business opportunity, thereby making participation in the tendering process beneficial for MNOs. By attracting multiple proposals from MNOs, the GA fosters competition, ensuring the best value for taxpayer funds. Therefore, the business model and project terms must support MNO profitability, enabling the GA to establish a partnership that facilitates the successful delivery of public safety services.

The contractual elements that enhance MNO profitability in public safety projects include a single-actor business model, adequate public funding for RAN costs, a large user base, a long contract period, and the opportunity for MNOs to leverage the enhanced RAN for standard business operations. Taking these factors into account makes public safety procurements more appealing to MNOs. In addition, the single-actor business model is expected to further support the project's success, while the multi-actor business model involves multiple parties, necessitating a careful focus on the division of responsibilities during the design, development, and operation phases.

5.5. Limitations of the study

This study assumes that the primary goal of the public safety project is to expeditiously replace narrowband solutions with an 4G/5G mobile broadband service. The assumed project model anticipates that the MNO's existing RAN network will be extended and that other capabilities will be developed to enable the full-scale deployment of MC services when public safety operations begin. This model requires substantial up-front investment. These basic assumptions reflect the European approach.

An alternative strategy would involve the contemporaneous use of existing narrowband public safety solutions and new mobile broadband capabilities, enhancing traditional voice services with data-rich applications. This approach allows for incremental implementation, avoiding the need for immediate and comprehensive network extensions or the full deployment of additional capabilities at the launch of broadband public safety services. Instead, new technologies and capabilities can be introduced incrementally, based on user needs and technological advancements – for example, leveraging low Earth orbit satellites to improve network coverage in rural areas (Höyhtyä et al., 2022). This alternative strategy is consistent with the framework used for FirstNet in the United States.

Comparing the two approaches could reveal whether the incremental model using narrowband and broadband together and introducing new services gradually requires less public funding and ensures MNO profitability.

6. Conclusion

This study explored MNOs' engagement with public safety mobile broadband projects in which MNO networks are shared with public safety users to deliver MC services. Focusing on the key factors behind MNO profitability, such as business models, network investments, public funding, and contract length, the researchers compared multi-actor and single-actor business models and assessed the impact of various business risks and opportunities on profitability. The study employed the DCF method with sensitivity analyses and used data from public sources, expert interviews, and existing public safety broadband projects in the United States and Europe.

The findings highlight the importance of substantial public funding in supporting investments for network enhancements and maintenance to ensure MNO profitability in public safety projects. Between the two business models analysed, the single-actor model used in the United States proved more profitable, offering a wider service portfolio and an ARPU three times higher than that of MNOs' standard mobile business. Moreover, public safety projects can significantly influence MNOs' standard mobile business by increasing or decreasing their market share. These changes in revenue can either enhance or diminish the overall profitability of public safety projects.

This study presented strategic recommendations for MNOs to improve the profitability of their public safety mobile broadband projects. It also provided policy proposals and guidance for GAs on applying these findings to define business models and contracts that encourage MNO participation in public safety projects and facilitate partnerships for the effective delivery of public safety services.

Exploring an area with limited prior research, this work represents an important research contribution, providing quantitative insights into MNOs' business dynamics in public safety broadband projects. Furthermore, the DCF model developed for analysing MNOs' public safety business offers valuable resources to support future research efforts.

The assumption of this study is that the primary objective of public safety projects is to swiftly replace existing narrowband public safety communication systems with new mobile broadband solutions, ensuring a short transition period. Future research could explore an alternative approach that combines the long-term coexistence of narrowband and broadband systems and the incremental introduction of new services. Such a comparison could evaluate MNO profitability and public funding requirements, offering insights into whether an incremental model might reduce public funding needs while sustaining MNO profitability.

CRediT authorship contribution statement

Tapio Savunen: Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Juuso Töyli:** Validation, Methodology. **Pekka Kekolahti:** Validation, Methodology. **Petri Mähönen:** Validation, Methodology.

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Appendix A. – DCF model revenue and cost items

Table A.1
DCF model revenue items

Revenue	Multi-actor business model	Single-actor business model
RAN enhancement – Fixed price		
Public funding	✔	✔
Connectivity service – Subscriber-based		
MC RAN connectivity service	✔	
MC end-to-end connectivity service		✔
Other services – Subscriber-based		
MCS application		✔
Public safety applications		✔
Devices and accessories		✔
Indirect revenue		
Mobile business growth	✔	✔

MC = mission-critical; RAN = radio access network; MCS = mission-critical services.

Table A.2
DCF model cost items

Cost	Multi-actor business model	Single-actor business model
RAN enhancement		
RAN coverage extension	CAPEX/OPEX	CAPEX/OPEX
RAN hardening – Radio site backup power supply	CAPEX/OPEX	CAPEX/OPEX
RAN hardening – Duplicated transmission links	CAPEX/OPEX	CAPEX/OPEX
Deployable network solutions	CAPEX/OPEX	CAPEX/OPEX
Cyber security hardening		
Cyber security audit and improvements	CAPEX/OPEX	CAPEX/OPEX
Connectivity service		
Cost of using existing RAN	OPEX	OPEX
Other services		
MCS application		CAPEX/OPEX
Public safety applications		OPEX
Devices and accessories		OPEX
Supporting resources		
Dedicated core network		CAPEX/OPEX
New IT solutions – Customer relationship management, service and device management		CAPEX/OPEX
Additional personnel – Key account management team	OPEX	
Additional personnel – Sales and marketing, customer support, partnership management		OPEX

RAN = radio access network; MCS = mission-critical services; OPEX = operating expenditure; CAPEX = capital expenditure.

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