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A Systematic Review of Business Models for 5G and 6G Networks



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A Systematic Review of Business Models for 5G and 6G Networks

Anestis-Christos Fotakidis

Abstract

The transition from fifth-generation (5G) mobile networks towards Beyond-5G (B5G) and sixth-generation (6G) systems is expected to reshape not only network capabilities but also the ways in which telecommunications services create, deliver, and capture value. However, the emerging 6G business-model literature remains fragmented across technological, economic, methodological, and institutional perspectives. This dissertation addresses this gap through a systematic literature review examining business model archetypes, the commercial relevance of technical enablers, evaluation approaches, and barriers to commercial realisation.

The review was informed by the PRISMA 2020 framework and covered literature published between January 2020 and May 2026 across six scholarly databases and publisher platforms. After deduplication and screening, 218 publications formed the common review corpus and were reassessed using criteria specific to each research question.

The findings indicate that 6G business-model development is characterised primarily by evolution and recombination rather than wholesale replacement of earlier telecommunications models. Platform and ecosystem-oriented configurations, slicing-based services, infrastructure sharing, capability-as-a-Service, and local or private network models form important components of this transition, while sustainability driven and decentralised marketplace configurations appear more prominently in emerging 6G research. Analysis of 112 attributable technical-enabler relationships further shows that technical capabilities are more frequently associated with broader business or economic value than with explicit monetisation. Network slicing provides the clearest link to direct value capture.

The methodological comparison shows that 5G research has a stronger operational and techno-economic evaluation profile, whereas 6G studies remain more prospective, conceptual, and ecosystem-oriented. Technical demonstration and business/economic validation represent distinct evidential dimensions. Finally, the barrier analysis indicates that commercial realisation depends on the combined alignment of economic viability, ecosystem coordination, monetisation, technical service realisation, organisational capabilities, and regulatory conditions. Overall, the dissertation frames emerging 6G business-model development as a problem of commercial translation and ecosystem alignment.

Keywords: 6G, 5G, business models, value creation, monetisation, techno-economic evaluation, network slicing, telecommunications ecosystems

Preface

The choice of this dissertation topic was motivated by academic interest and the interdisciplinary nature of future mobile-network development. My academic background is primarily rooted in economics, while the study of 5G, Beyond-5G, and 6G business models lies at the intersection of economics, business strategy, information technology, and telecommunications. This combination provided an opportunity to examine technological development not only from a technical perspective, but also through questions of economic value, commercial viability, investment, market structure, and business-model innovation.

The development of 6G is particularly relevant because emerging network technologies may introduce new capabilities while reshaping relationships among network operators, infrastructure providers, digital platforms, vertical industries, and other ecosystem participants. Understanding these developments therefore requires connecting technological innovation with the mechanisms through which value is created, delivered, and captured.

Working on this dissertation allowed me to deepen my understanding of telecommunications technologies and the economic and organisational dimensions of their deployment. It also provided practical experience in conducting a systematic literature review, evaluating heterogeneous academic evidence, and distinguishing technological feasibility from commercial viability.

More broadly, the study offered an opportunity to bridge two increasingly interconnected fields and explore how technological innovation can be translated into sustainable economic value.

Περίληψη

Η μετάβαση από τα δίκτυα πέμπτης γενιάς (5G) προς τα Beyond-5G (B5G) και τα συστήματα έκτης γενιάς (6G) αναμένεται να μετασχηματίσει τις δυνατότητες των δικτύων και τους τρόπους με τους οποίους οι τηλεπικοινωνιακές υπηρεσίες δημιουργούν και εξασφαλίζουν αξία. Ωστόσο, η βιβλιογραφία για τα επιχειρηματικά μοντέλα 6G παραμένει κατακερματισμένη μεταξύ τεχνολογικών, οικονομικών, μεθοδολογικών και θεσμικών προσεγγίσεων.

Η ανασκόπηση βασίστηκε στο πλαίσιο PRISMA 2020 και κάλυψε δημοσιεύσεις από τον Ιανουάριο του 2020 έως τον Μάιο του 2026 σε έξι επιστημονικές βάσεις και εκδοτικές πλατφόρμες. Αφού απομονώθηκαν τα διπλότυπα και έγινε έλεγχος συνάφειας, 218 δημοσιεύσεις συγκρότησαν την βάση δεδομένων της εργασίας και επανεξετάστηκαν με ειδικά κριτήρια.

Τα ευρήματα καταδεικνύουν ότι η εξέλιξη των επιχειρηματικών μοντέλων προς το 6G χαρακτηρίζεται κυρίως από συνέχεια και ανασύνθεση προγενέστερων μοντέλων και όχι από αντικατάστασή τους. Διαμορφώσεις σε πλατφόρμες και σε οικοσυστήματα, network slicing, κοινή χρήση υποδομών, capability-as-a-Service και τοπικά ή ιδιωτικά δίκτυα αποτελούν βασικά στοιχεία της μετάβασης, ενώ μοντέλα βιωσιμότητας και αποκεντρωμένων αγορών εμφανίζονται εντονότερα στη βιβλιογραφία 6G. Η ανάλυση των τεκμηριωμένων τεχνολογικών σχέσεων δείχνει ότι οι τεχνικές δυνατότητες συνδέονται συχνότερα με ευρύτερη επιχειρηματική ή οικονομική αξία παρά με ρητούς μηχανισμούς χρηματικής αξιοποίησης, με το network slicing να παρουσιάζει τη σαφέστερη σύνδεση με άμεση σύλληψη αξίας.

Η μεθοδολογική σύγκριση έδειξε ότι η βιβλιογραφία 5G έχει ισχυρότερο λειτουργικό και τεχνοοικονομικό προσανατολισμό, ενώ οι μελέτες 6G παραμένουν περισσότερο προοπτικές, εννοιολογικές και πολυπαραγοντικές. Η τεχνική δοκιμή και η επιχειρηματική ή οικονομική επικύρωση αποτελούν διακριτές διαστάσεις τεκμηρίωσης. Τέλος, η εμπορική υλοποίηση εξαρτάται από οικονομική βιωσιμότητα, συντονισμό οικοσυστήματος, μηχανισμούς εσόδων, τεχνική υλοποίηση, οργανωσιακές ικανότητες και ρυθμιστικές συνθήκες. Συνολικά, η εργασία προσεγγίζει την ανάπτυξη επιχειρηματικών μοντέλων 6G ως διαδικασία μετατροπής των τεχνολογικών δυνατοτήτων σε εμπορικά αξιοποιήσιμη αξία και ευθυγράμμισης του επιχειρηματικού οικοσυστήματος, εξετάζοντας παράλληλα τις μεθόδους αξιολόγησης και τα οικονομικά, οργανωσιακά, τεχνικά και ρυθμιστικά εμπόδια που επηρεάζουν την εμπορική τους υλοποίηση.

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List of Abbreviations

5G	Fifth Generation
6G	Sixth Generation
AI	Artificial Intelligence
ARPU	Average Revenue per User
B5G	Beyond 5G
BM	Business Model
CAPEX	Capital Expenditure
CCAM	Cooperative, Connected and Automated Mobility
DetNet	Deterministic Networking
EC	Exclusion Criteria
eMBB	Enhanced Mobile Broadband
eSIM	Embedded Subscriber Identity Module
FD-RAN	Fully Decoupled Radio Access Network
FSO	Free-Space Optical
HAPS	High-Altitude Platform Station
IC	Inclusion Criteria
IoT	Internet of Things
LEO	Low Earth Orbit
MEC	Multi-access Edge Computing
MIMO	Multiple-Input Multiple-Output
ML	Machine Learning
mmWave	Millimetre Wave
MNO	Mobile Network Operator
mMTC	Massive Machine-Type Communication

MVNO	Mobile Virtual Network Operator
NFV	Network Functions Virtualisation
NPV	Net Present Value
NTN	Non-Terrestrial Network
OPEX	Operational Expenditure
PoC	Proof of Concept
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
QoS	Quality of Service
RAN	Radio Access Network
ROI	Return on Investment
RQ	Research Question
SDN	Software-Defined Networking
SEP	Search Eligibility Parameters
SLA	Service-Level Agreement
SlaaS	Slice-as-a-Service
SLR	Systematic Literature Review
TCO	Total Cost of Ownership
THz	Terahertz
TSN	Time-Sensitive Networking
UAV	Unmanned Aerial Vehicle
URLLC	Ultra-Reliable Low-Latency Communication
VP	Value Proposition

1. Introduction

Mobile communication networks are evolving from increasingly capable fifth-generation (5G) systems toward a broader sixth-generation (6G) vision intended to address service requirements expected beyond 2030. While 5G introduced enhanced mobile broadband, massive machine-type communication, and ultra-reliable low-latency communication alongside increasingly virtualised and programmable network architectures, emerging 6G concepts extend these developments toward substantially higher data rates and connection densities, lower latency, near-global coverage, more precise localization and synchronization, and increasingly autonomous network operation. Realizing these capabilities is associated with a wider combination of artificial intelligence and machine learning, non-terrestrial networks, new spectrum ranges, network softwarisation, dynamic network slicing, and distributed cloud and edge computing. In this sense, 6G is increasingly envisioned not merely as an incremental radio-access upgrade, but as a more integrated and intelligent communication environment capable of combining connectivity, computing, automation, and heterogeneous terrestrial and non-terrestrial resources [1].

The significance of this transition, however, is not limited to improvements in network performance. Emerging 6G visions also broaden the objectives through which future mobile networks are expected to generate value, incorporating sustainability, digital inclusion, intelligent automation, local and campus deployments, and new forms of interaction between physical and digital environments. Such developments may reshape existing value chains and increase the importance of digital platforms and multi-actor ecosystems in the creation and capture of value [2]. At the same time, B5G and 6G architectures are expected to enable increasingly differentiated and user-centric services through virtualization, cloud technologies, network slicing, and programmable resource management. These capabilities can support heterogeneous vertical requirements and on-demand service provision, but they also imply that the creation, delivery, and consumption of network resources may need to be reconsidered from both technological and business perspectives [3]. Consequently, evaluating future networks exclusively through conventional technical performance indicators would provide an incomplete account of their broader economic and strategic significance.

The business implications of this transformation are already visible in the evolution of 5G. Rather than functioning solely as a uniform connectivity upgrade, 5G can be understood as a configurable set of capabilities incorporating network slicing, virtualization, mobile edge computing, private networking, and increasingly flexible forms of spectrum and infrastructure use. These characteristics enable differentiated service configurations while widening the range of actors that may participate in network provision and service delivery [4]. In parallel, increasing network programmability and modularity support a broader process of platformisation. As competitive pressure increases around basic connectivity services, operators may seek new positions in business-to-business markets, cloud and IoT services, digital platforms, and other ecosystem-based arrangements. This can shift value creation away from purely vertically controlled operator structures toward networked configurations in which several actors jointly create, deliver, and capture value [5]. More broadly, technological evolution is occurring alongside changes in competition, regulation, investment patterns, and the participation of firms from adjacent industries, reducing the explanatory power of a traditional linear value-chain perspective and increasing the relevance of value-network and ecosystem approaches [6].

The existence of advanced technical capabilities, however, does not guarantee successful commercialisation. Research on digital transformation more generally indicates that investment in digital technologies alone does not necessarily generate equivalent business value or competitive

advantage. Organizations may need to redesign the mechanisms through which they create, deliver, and capture value in order to benefit from technological innovation, making business-model innovation an important managerial complement to digital transformation [7]. Experience from the commercialisation of 5G provides a practical illustration of this challenge. Evidence from the South Korean market shows that, despite early deployment and considerable expectations surrounding 5G-enabled vertical applications, subscriber growth and the development of several anticipated service markets progressed more slowly than initially expected. Service-quality limitations, the absence of sufficiently compelling applications, and constraints on infrastructure investment were among the factors identified as limiting wider market activation [8]. These observations are particularly relevant for B5G and 6G, since they suggest that technological readiness alone may be insufficient without viable service propositions, investment incentives, appropriate business models, and coordinated ecosystem development.

The increasing diversity of actors and service configurations also makes the assessment of future-network business propositions more complex. A single technological use case may correspond to several alternative arrangements concerning stakeholder roles, infrastructure ownership, resource sharing, pricing, cost and revenue allocation, and market participation. Consequently, determining whether a proposed configuration is commercially viable requires analytical approaches that consider not only technical deployment but also actor-level incentives, cost structures, revenues, uncertainty, and the potential for replication or scaling [9]. This need is reinforced by the structure of the existing strategic literature. Although research on advanced mobile networks has expanded considerably, the 5G literature remains fragmented across specific applications, industries, and analytical perspectives, while much of the wider research effort has historically remained strongly technology-oriented. Strategic questions concerning business-model transformation, ecosystem reconfiguration, and the creation, delivery, and capture of value have therefore received less integrated treatment [10].

Overall, these developments indicate that the transition toward 6G should be examined as both a technological and a business-system transformation. Future mobile-network research must therefore consider not only which technological capabilities become available, but also how these capabilities are translated into value propositions, how new actor configurations and mechanisms of value capture emerge, how proposed business models are evaluated, and which technical, economic, organisational, and regulatory conditions may limit their realisation. A systematic synthesis across these dimensions is particularly important during the present transition from commercially deployed 5G systems toward the still-emerging 6G landscape.

1.1 Research aim and research questions

The aim of this study is to systematically investigate the emerging business-model landscape associated with the transition from 5G and Beyond-5G (B5G) toward 6G. The study examines this transition through four complementary dimensions: the business-model configurations proposed or studied in the literature; the relationship between technical enablers and mechanisms of value creation and capture; the methodological approaches and validation strategies used to evaluate related business propositions; and the barriers, risks, and open challenges that may constrain their realisation.

Given the comparatively early technological and commercial maturity of 6G, the study adopts a cross-generational perspective rather than assuming that an independent and fully established 6G business-model landscape already exists. Evidence from 5G is therefore used, where analytically appropriate, to identify commercial structures, value mechanisms, evaluation practices, and implementation challenges that may provide antecedents to future-network development. At the same time, 5G precursor, B5G

transition, cross-generational, and direct-6G evidence are distinguished throughout the analysis in order to avoid interpreting experience from earlier network generations as direct confirmation of future 6G outcomes.

To address this aim, the study is guided by the following research questions:

RQ1: Which business model archetypes (e.g., Network-as-a-Service, platform-based, slice-as-a-service, infrastructure sharing) have been proposed or studied for 6G networks in the academic literature?

RQ2: Which technical enablers of 6G (e.g., AI-native networks, network slicing, edge/cloud continuum, integrated sensing and communication) are linked to new value propositions or revenue streams in proposed business models?

RQ3: Which methodological approaches and validation strategies are used to evaluate 5G- and 6G-related business models, and how do these approaches differ between the 5G and 6G literature?

RQ4: Which barriers, risks, or open challenges (technical, economic, organisational, regulatory) are identified in the literature as obstacles to realizing proposed 6G business models?

Together, the four research questions examine the emerging business-model landscape from complementary perspectives: what business-model configurations are being proposed, which technological capabilities may support their value propositions, how these propositions are being evaluated, and which conditions may hinder their practical realisation.

1.2 Contribution of the study

This study contributes an integrated and cross-generational synthesis of the literature on business models for future mobile networks. Rather than examining business-model propositions, technical opportunities, evaluation methods, and implementation challenges as separate research streams, the review brings these dimensions together within a common analytical framework. This enables the emerging 6G business-model landscape to be examined not only in terms of the commercial configurations being proposed, but also in relation to their technological foundations, evidential maturity, and conditions for realisation.

First, the study provides a structured synthesis of recurrent business-model archetypes and examines their evolutionary positioning across 5G, B5G, cross-generational, and direct-6G research. This distinction makes it possible to differentiate commercial structures that are predominantly inherited from 5G from configurations that show stronger continuity across generations and those that appear more prominently within the emerging 6G literature.

Second, the study develops a source-level synthesis linking technical enablers to value propositions and mechanisms of value capture. By distinguishing explicit direct-monetisation mechanisms from broader business or economic value, the analysis avoids equating technical benefit or general revenue potential with evidence of an identifiable transaction mechanism. This provides a more detailed account of how network capabilities may contribute to business-model development and where the transition from value creation to explicit value capture remains incomplete.

Third, the study compares the methodological approaches and validation strategies used in 5G and 6G related business-model research. In doing so, it distinguishes business/economic evaluation maturity from supporting technical evidence and therefore avoids treating technical simulation, prototypes, or testbeds as equivalent to validation of commercial viability. The comparison provides a structured

indication of how the evidential basis of future-network business-model research changes across technological generations.

Fourth, the study synthesises technical, economic/commercial, organisational/ecosystem, and regulatory/institutional barriers within a common business-model realisation perspective. This allows implementation challenges to be interpreted not as isolated obstacles but as interconnected conditions affecting investment viability, monetisation, ecosystem coordination, service realisation, and regulatory feasibility.

Methodologically, the review applies RQ-specific analytical boundaries and evidence requirements to a common corpus of 218 publications. This design preserves a consistent underlying literature base while allowing the unit of analysis and evidential threshold to reflect the specific objective of each research question. The systematic distinction between precursor and direct-6G evidence further supports a cautious interpretation of an emerging research field in which technological expectations and commercial maturity remain uneven.

Overall, the contribution of the dissertation lies in connecting four questions that are necessary for assessing the maturity of emerging 6G business models: what is being proposed, what technological capabilities may support it, how convincingly it has been evaluated, and what remains unresolved before practical realisation.

1.3 Structure of the dissertation

The remainder of the dissertation is structured as follows. The chapter following the introduction establishes the technological and business context for the transition from 5G toward B5G and 6G. It introduces the network developments most relevant to future business-model formation and outlines the concepts of business models, value creation and capture, value networks, ecosystems, and related forms of digital and service-oriented business transformation.

The subsequent methodology chapter describes the design of the systematic literature review, including the scoping process, search strategy and information sources, deduplication and screening procedures, study-selection criteria, and the formation of the common review corpus. It also establishes the basis for the RQ-specific analytical procedures applied throughout the study.

The main analytical part of the dissertation then addresses the four research questions sequentially. RQ1 examines the business-model archetypes identified in the literature and their positioning across the transition from 5G to 6G. RQ2 analyses how technical enablers are associated with value propositions and mechanisms of value creation and capture. RQ3 compares the methodological approaches, evaluation strategies, and evidence maturity of 5G and 6G-related business-model research. RQ4 synthesises the technical, economic, organisational, and regulatory barriers that may constrain the realisation of proposed future-network business models.

Each RQ-specific chapter presents the corresponding results and subsequently discusses their implications. The findings are then integrated in a cross-RQ synthesis that considers what the four research questions collectively imply about the maturity and evolution of the emerging 6G business-model landscape. The dissertation concludes by summarising the principal findings and identifying directions for future research.

2. Background and Theoretical Context

Future mobile-network development can be understood as an evolutionary process in which capabilities established through 5G provide part of the technological basis for increasingly distributed, heterogeneous, and intelligent network environments. Emerging 6G research extends this trajectory toward more integrated architectures and deeper use of artificial intelligence across multiple layers and functions of network operation. AI-enabled techniques are being considered for functions such as resource allocation, scheduling, mobility management, routing, traffic prediction, and network orchestration, while their wider integration introduces additional requirements concerning computational resources, data availability, privacy, energy consumption, distributed processing, and interoperability [11]. These developments provide the technological context within which the broader business and organisational implications of the transition toward B5G and 6G can be examined.

2.1 From 5G to B5G and 6G

The evolution from fifth-generation (5G) mobile networks toward Beyond-5G (B5G) and sixth-generation (6G) systems is characterised by both continuity and architectural transformation. Several technologies introduced or substantially developed within 5G, including network slicing, edge computing, network virtualisation, software-defined networking, and support for industrial and vertical applications, are expected to remain important components of future mobile-network architectures rather than being replaced by an entirely independent technological paradigm. At the same time, emerging 6G systems are expected to extend these developments toward more heterogeneous, distributed, programmable, and intelligent network environments capable of supporting increasingly diverse service requirements [11], [12].

A central feature of this evolution is the growing separation of network functions from dedicated proprietary hardware. Traditional telecommunications infrastructures commonly relied on tightly coupled hardware and software components, whereas SDN, NFV, and network virtualisation enable network functions to operate on general-purpose computing infrastructure and to be instantiated, relocated, or reconfigured more flexibly. This architectural shift is further reinforced by cloudification, through which telecommunications central offices increasingly resemble distributed data-centre environments capable of hosting virtualised network functions alongside computing and storage resources [13], [14]. Cloud-native network functions, service-function chaining, and increasingly software-based network components therefore extend the transition from static, hardware-dependent infrastructures toward more modular and dynamically managed network architectures [14].

Network slicing represents an important example of how these architectural developments can be translated into differentiated service provision. By creating logically isolated and customisable networks over shared physical infrastructure, slicing enables network resources to be allocated according to the requirements of different tenants, services, and vertical industries. Its implementation relies strongly on SDN and NFV, which provide programmable control, virtualised network functions, and the ability to orchestrate resources across radio-access, transport, core-network, and computing domains [12]. Although slicing was introduced and developed within 5G, it is expected to remain relevant in 6G, where increasingly heterogeneous applications may require more complex combinations of bandwidth, latency, reliability, computing, security, and connectivity characteristics [11], [12].

The progression toward 6G also involves a broader shift from predominantly centralised network architectures toward more distributed configurations. Future systems are expected to make greater use

of end-to-end slicing, distributed computing and data processing, integrated terrestrial and non-terrestrial connectivity, and increasingly flexible coordination of resources from the network edge to the core [11]. Cloudification and disaggregation contribute to this transition by moving network functions away from specialised equipment and toward virtualised and general-purpose infrastructure, thereby supporting more flexible placement of functions and closer integration between connectivity, computing, and storage resources [13]. However, these changes also introduce new operational and architectural trade-offs. Greater modularity and openness increase the need for effective resource management, integration, and orchestration across multiple platforms, infrastructure components, and administrative domains [14].

This architectural evolution is further associated with increasing convergence across virtualised, software-defined, cloud-based, and distributed network environments. Future connectivity is expected to span a wider range of heterogeneous devices and infrastructures, while distributed resource management and intelligent orchestration become increasingly important as services extend across terrestrial and non-terrestrial domains [15]. Such developments also create greater scope for decentralised forms of coordination and resource sharing across increasingly complex network environments, although their practical implementation depends on mechanisms capable of maintaining trust, scalability, interoperability, and efficient resource management [15].

Artificial intelligence and machine learning are expected to become increasingly embedded within this evolving architecture. Rather than being limited to end-user applications, AI-enabled techniques are being considered across the physical, data-link, and network layers for functions including channel estimation, resource allocation, scheduling, handover management, slicing, traffic prediction, orchestration, mobility management, load balancing, and routing [11]. This deeper integration of AI supports the broader objective of creating networks that can adapt more dynamically to changing traffic patterns, service requirements, and operating conditions. At the same time, the use of AI introduces additional requirements concerning computational resources, training data, privacy, energy consumption, distributed processing, and interoperability, indicating that greater network intelligence also increases the complexity of network design and operation [11].

The need for this increased flexibility is also visible in emerging application environments. Immersive and interactive services, such as those associated with virtual and augmented environments, illustrate the difficulty of satisfying future service requirements through improvements in a single performance dimension. Such applications may simultaneously depend on high bandwidth, low latency, reliable real-time communication, dense device connectivity, security, and seamless interaction across multiple devices and environments [16]. Although 5G provides substantial improvements in several of these areas, increasingly data-intensive applications can expose continuing constraints related to coverage, congestion, energy consumption, interoperability, and security [16].

These expectations should nevertheless be interpreted cautiously. Many frequently cited 6G performance targets remain projections derived from early research and standardisation visions rather than empirically demonstrated characteristics of commercially deployed systems [16]. Consequently, the transition toward 6G should not be understood simply as the attainment of a predetermined set of performance targets, but as an ongoing technological evolution whose eventual capabilities and deployment configurations remain subject to further development and validation.

Taken together, these developments indicate that the transition toward B5G and 6G is not defined solely by improvements in radio performance. It also involves a progressive transformation of mobile networks into more software-based, cloudified, virtualised, distributed, and programmable environments.

Network functions can increasingly be decoupled from dedicated hardware, resources can be shared and dynamically configured, and connectivity can be integrated more closely with computing, storage, orchestration, and intelligence [12], [13], [14]. These architectural changes provide the technological foundation for more flexible and service-oriented forms of network provision, which are examined in the following section.

2.2 From Connectivity Provision to Programmable and Service-Oriented Networks

The increasing softwarisation of mobile networks is changing not only how telecommunications infrastructure is operated, but also how network capabilities can be exposed and consumed. Through technologies such as network virtualisation and software-defined networking, resources that were previously embedded within relatively static network configurations can increasingly be instantiated, reconfigured, and allocated dynamically. This enables external customers, including vertical industries, to request combinations of connectivity, computing, and network functions that are more closely aligned with their specific service requirements rather than relying exclusively on predefined connectivity products [17].

Network slicing provides a particularly clear example of this transition. Virtualised connectivity and computing resources from a common physical infrastructure can be combined into customer-specific end-to-end logical networks, while automation enables these slices to be provisioned on demand. This model provides the technical basis for Slice-as-a-Service, in which the underlying infrastructure remains shared while the customer receives a logically dedicated service environment. Depending on the arrangement, the operator may retain full management responsibility or expose selected programmability and control capabilities to the customer, allowing network functions and connectivity to be adapted dynamically during the lifetime of the service [17].

The same service-oriented logic extends beyond logical connectivity to distributed computing resources. Mobile-edge architectures allow virtualised execution environments to be positioned close to users and offered across geographically distributed locations as an on-demand service. In such scenarios, computing resources can be consumed on a pay-as-you-go basis and governed through service-level requirements concerning latency, bandwidth, availability, and service continuity [18]. Service functions may also be migrated or proactively instantiated at different edge locations as operating conditions or user locations change, making dynamic resource allocation an integral part of service delivery [18].

These developments indicate a broader transition from the provision of connectivity as a relatively uniform network product toward the provision of configurable network capabilities. Connectivity, computing, storage, virtual network functions, and orchestration can increasingly be combined into service-specific configurations whose composition changes according to the needs of a customer or application. The resulting service environment is therefore defined not only by access to the network but also by the ability to configure, manage, scale, and coordinate the resources supporting a particular service [17], [18].

This transition also has implications for the strategic role of connectivity providers. Evidence from the IoT domain suggests that providers can extend their value-creation logic beyond basic network access toward cloud-service provision, technical solutions, and broader business solutions. Such diversification requires changes not only in the technical service portfolio but also in the provider's business model, including its value proposition, capabilities, partnerships, and mechanisms of value creation [19]. The evolution toward programmable and service-oriented networks can therefore support a broader

repositioning of telecommunications providers from connectivity suppliers toward providers of configurable digital capabilities and integrated service solutions.

The implications of this transformation also extend to the organisation of the wider service ecosystem. Evidence from connected-vehicle services illustrates how advanced connectivity and computing capabilities can require closer cooperation between mobile operators, automotive manufacturers, cloud providers, infrastructure providers, and specialised service actors. In such settings, traditional linear value-chain relationships can evolve toward value networks in which multiple participants combine resources and capabilities to deliver a service [20]. Individual technical capabilities may enhance existing propositions, enable new services, alter the roles of established participants, or create opportunities for new stakeholders within the ecosystem [20].

Similar changes can be observed in the management of connectivity itself. In machine-to-machine eSIM environments, remote provisioning allows connectivity profiles to be managed dynamically and distributes technical control across network operators, equipment manufacturers, and specialised service providers. The resulting commercialisation arrangements vary according to which actor controls the underlying provisioning and management functions, illustrating how digitalisation can reshape both operational responsibilities and positions within the connectivity ecosystem [21].

Importantly, greater technical configurability does not by itself determine how commercial value will ultimately be realised. The economic significance of an enabling capability depends on how it is incorporated into a service, the actors involved, the underlying business model, the allocation of value among participants, the use case, and the surrounding regulatory conditions [20]. Programmability and virtualisation should therefore be understood as enabling conditions for service-oriented business transformation rather than as business models in themselves. By making network capabilities more modular, configurable, and externally accessible, they expand the range of services and actor arrangements that can potentially be built on top of future mobile-network infrastructure.

Taken together, these developments indicate that the evolution of telecommunications services involves more than the introduction of new network functions. Softwarisation, programmability, virtualisation, edge computing, and digitalised service management make network capabilities increasingly modular, configurable, and accessible to external customers. These capabilities can support connectivity services, cloud and edge resources, customer-specific logical networks, technical solutions, and more integrated service propositions [17], [18], [19]. Their commercial significance, however, depends on how they are incorporated into business models and coordinated across the actors participating in the service ecosystem [20], [21]. This distinction between technological capability and business-model configuration provides the basis for the following section on business models and business-model innovation.

2.3 Business Models and Business-Model Innovation

A business model provides an abstract representation of the underlying logic through which an organisation structures its activities and creates economic value. It extends beyond the product or service being offered and the mechanism through which revenues are generated, encompassing interconnected decisions concerning the value proposition, resources, organisational processes, partners and suppliers, customers, delivery arrangements, cost structure, and revenue model [22]. The analytical significance of a business model therefore lies not only in the presence of these individual components but also in the degree of coherence between them. A viable business model requires alignment between the

organisation's value proposition, resources, activities, market relationships, and mechanisms of value capture within the broader strategic direction of the firm [22].

The mechanisms through which organisations create value can nevertheless differ substantially. One useful distinction is between value chains, value shops, and value networks. Value chains create value primarily through sequential transformation activities, while value shops rely on specialised knowledge and problem solving. Value networks, by contrast, create value by facilitating and mediating interactions among multiple participants [23]. This distinction is particularly relevant in digital environments, where the value network does not necessarily correspond to the physical infrastructure supporting the service. Telecommunications networks, for example, may provide the underlying connectivity required for interaction, while the economic value network consists of the relationships among users, service providers, infrastructure providers, and other participating actors [23].

Digitalisation further changes the relationship between technological capabilities and business models. Digital technologies can enable new services, customer interactions, operating processes, and value propositions, but technological novelty does not by itself create economic value. Its commercial significance depends on how technological capabilities are incorporated into a coherent business model and connected to an appropriate value proposition, organisational structure, delivery mechanism, and form of value capture [22]. The relationship between technology and the business model is therefore reciprocal: technological development may enable new business-model configurations, while the business model determines how those technologies are organised, brought to market, and converted into economic value [22].

Business-model innovation can consequently be distinguished from narrower forms of product or process innovation. Product innovation primarily concerns the introduction or improvement of an offering, while process innovation concerns changes in the way goods or services are produced, distributed, or delivered. Business-model innovation involves a broader change in how an organisation creates, delivers, and captures value [24]. The adoption of a new technology should therefore not automatically be interpreted as evidence of business-model innovation. The same technological capability can lead to substantially different strategic and economic outcomes depending on how it is incorporated into the organisation's business model and combined with complementary resources and organisational capabilities [24].

Technological change is also not the only driver of such transformation. Innovation can arise through technology-push mechanisms, in which new technological capabilities create previously unavailable opportunities, but it may also result from market-pull mechanisms, in which customer requirements, stakeholder expectations, competitive pressure, or other market developments stimulate organisational adaptation [24]. From this perspective, the relevant issue is not the adoption of technology for its own sake, but the degree of fit between technological functionality, market requirements, and the broader configuration through which value is produced. Evidence from digital-transformation contexts further suggests that matching technological capabilities with stakeholder needs can be more important than pursuing a predetermined set of technologies simply because they are available [24].

Servitisation provides a useful illustration of the extent to which business-model innovation can involve simultaneous changes across several business-model components. Moving from predominantly product-oriented provision toward service-oriented arrangements can alter the value proposition, revenue mechanism, ownership structure, customer relationship, organisational capabilities, partner network, and distribution of operational and financial risk [25]. Service-oriented configurations may range from traditional products supplemented by services to arrangements based on access, actual usage, or agreed

performance outcomes. These alternatives represent different combinations of value creation and capture and allocate ownership, responsibility, and risk differently between provider and customer [25].

This continuum also demonstrates why an individual revenue mechanism should not be treated as a complete business model. Fixed recurring fees, pay-per-use arrangements, leasing, subscriptions, or performance-based payments represent particular mechanisms of value capture, but their commercial meaning depends on the broader configuration of resources, activities, service responsibilities, customer relationships, contractual conditions, and risk allocation supporting them [25]. Empirical research on product-service-system business models similarly indicates that service-oriented models can assume multiple configurations involving different value propositions, customer groups, delivery channels, platform roles, ownership arrangements, and revenue streams [26]. Business models are therefore better understood as configurations of mutually dependent elements rather than as isolated pricing or service choices.

The translation of technological capability into customer or stakeholder value can also be understood as a process linking technical enablers, service delivery, interaction, and business organisation. Research on AI-enabled services, for example, distinguishes between the technologies enabling the service, the interfaces through which providers and customers interact, and the business arrangements through which the resulting service is organised and delivered [27]. From this perspective, technologies contribute to value creation through their integration into service processes rather than through technical functionality alone. Connectivity, data collection, computation, communication, and control can support value co-creation when they are embedded within service configurations that facilitate meaningful interaction between providers and customers [27].

Digital business environments can also weaken the traditional assumption that value creation and value capture occur within the same transaction or through the same stakeholder. In multi-actor and platform-based environments, one participant group may contribute to or receive value while revenues are generated through another group [22]. Value networks further reinforce this distinction because their economic logic depends on relationships among multiple participants, network effects, and combinations of cooperation and competition rather than solely on a linear transaction between producer and customer [23]. Understanding a digital business model therefore requires consideration not only of what value is created, but also for whom it is created, which actors participate in its delivery, and through which mechanisms economic value is ultimately captured.

Taken together, these perspectives suggest that a business model should be understood as a coherent configuration through which technological and organisational resources are translated into a value proposition, delivered through a set of activities and relationships, and connected to mechanisms of value capture. Business-model innovation occurs when this configuration is substantively altered rather than when a new technology is simply introduced into an otherwise unchanged operating logic [22], [24]. In increasingly digital and networked environments, such transformation may also redistribute value creation and capture across multiple organisations, customers, and complementary actors, making business models progressively dependent on wider value networks and ecosystem relationships [23]. These interdependencies provide the conceptual basis for the following discussion of value networks, ecosystems, and platformisation.

2.4 Value Networks, Ecosystems and Platformisation

The increasing distribution of value creation across multiple organisations has strengthened the relevance of an ecosystem perspective for understanding digital and future mobile-network business

models. Rather than representing only a technological environment, the emerging 6G ecosystem can be conceptualised as a configuration involving technological capabilities, a broader strategic vision, multiple stakeholder groups, and the business models through which these participants organise and exchange value [28]. This perspective extends the analysis beyond the technical network itself and recognises the growing interdependence between technological, business, regulatory, and societal dimensions.

A defining characteristic of such ecosystems is the diversity of the actors involved. Alongside traditional telecommunications stakeholders such as mobile network operators, equipment manufacturers, and application providers, emerging configurations may incorporate micro-operators, edge-cloud providers, resource brokers, vertical industries, and other specialised service actors [28]. Individual organisations may therefore contribute different combinations of infrastructure, technological capabilities, data, customer relationships, or specialised services rather than relying on a single vertically integrated provider to deliver the complete value proposition. The ecosystem perspective consequently shifts attention from the activities of an individual firm toward the relationships and complementarities among the actors required to realise a service.

Within this multi-stakeholder environment, value creation can become increasingly collective. Ecosystem-oriented business models emphasise value co-creation and co-capture, whereby participating actors contribute resources and capabilities to a shared service environment and derive value through their combined activities [28]. This changes the analytical focus from a purely bilateral provider–customer relationship toward a network of interdependent participants whose respective roles influence both the service being delivered and the way in which the resulting value is distributed. Such arrangements can also involve simultaneous cooperation and competition as firms collaborate in the delivery of common services or infrastructure while retaining distinct commercial objectives.

The emergence of local and specialised network operators provides a concrete illustration of how ecosystem roles may become more diverse. Micro-operators are conceived as locally focused providers serving particular industrial, commercial, or public environments through private or locally deployed networks. Depending on the specific configuration, they may provide connectivity directly to vertical customers, combine connectivity with specialised services, or act as neutral hosts supporting customers of traditional mobile network operators [29]. Such arrangements illustrate how responsibilities that have traditionally been concentrated within nationwide operators can become distributed across more specialised actors and locally configured service ecosystems. They also highlight the importance of contractual relationships and coordination between incumbent operators, local providers, infrastructure owners, and vertical customers [29].

Platformisation provides an additional mechanism through which these increasingly complex relationships can be organised. Emerging 6G research anticipates greater use of platform-based ecosystem business models capable of bringing together different stakeholder groups and facilitating the exchange of network resources, services, and digital capabilities [28]. In more decentralised configurations, platforms may develop into transaction environments or marketplaces through which virtualised network resources can be accessed, shared, or combined by multiple participants [28]. The business significance of a platform therefore extends beyond its technical implementation: a platform can also structure participation, mediate interactions, and influence the conditions under which resources and services are exchanged across the ecosystem.

The development of such platform-based arrangements also depends on organisational capabilities. Digital platform enterprises are characterised by multi-sided structures and distributed interactions, but

their evolution requires more than the introduction of new technological functionality. Organisations must be capable of mobilising and orchestrating internal and external resources, coordinating complementary capabilities, and adapting their organisational arrangements as platform activities become more complex [30]. An ecosystem-oriented understanding of platform business models therefore requires attention to the interdependencies between technological resources, organisational capabilities, value propositions, and participating actors rather than treating these elements in isolation [30].

The effectiveness of multi-platform ecosystems also depends on interoperability. Heterogeneous platforms, devices, applications, and service environments must be capable of interacting if resources and capabilities are to be combined across organisational and technological boundaries. Open interfaces and application programming interfaces can support this process by enabling different systems and service providers to discover, access, and integrate capabilities without requiring all participants to operate through a single homogeneous platform [31]. Interoperability can consequently act as an ecosystem-enabling mechanism, allowing independent providers to cooperate in the delivery of integrated services while retaining the ability to differentiate their own products and service offerings [31]. In this sense, openness concerns not only participation but also the technical capacity to connect otherwise heterogeneous resources and services.

The practical implications of this platform logic can be observed in 5G-enabled connected-mobility environments. The 5GMETA platform, for example, was designed to connect vehicle-data producers and consumers while making shared data resources available to third-party applications and services [32]. Such a configuration can bring together telecommunications operators, automotive manufacturers, infrastructure and road operators, public authorities, application developers, mobility-service providers, and other actors around a common platform. Value creation in this setting depends on combining data, connectivity, infrastructure, and service-development capabilities rather than on the contribution of a single organisation [32]. The example also illustrates how platform-based arrangements can generate new partnerships and require explicit coordination of the contributions made by different ecosystem participants.

The growing importance of platforms is closely related to broader tendencies toward openness and resource sharing. Future-network ecosystems may involve the sharing of infrastructure, spectrum, data, computing resources, and virtualised network capabilities, creating opportunities for more collaborative forms of service provision [28]. Greater openness, however, also increases the importance of ecosystem governance. Participation by local or specialised providers can depend on contractual arrangements, infrastructure-access rights, spectrum authorisation, and the regulatory recognition of new provider roles [29]. Ecosystem development therefore involves not only the establishment of technological interfaces but also the creation of rules, responsibilities, and coordination mechanisms that determine how actors participate and how shared resources are governed.

The concept of a 6G ecosystem nevertheless remains emergent and should be interpreted cautiously. Existing research employs numerous overlapping concepts, including wireless, telecommunications, network, business, software, and other ecosystem formulations, without always defining them consistently [28]. The ecosystem perspective should therefore not be interpreted as evidence that a single or fully established 6G market structure already exists. Rather, it provides an analytical framework for examining how increasingly distributed technological resources, stakeholder roles, business relationships, and institutional arrangements may become coordinated as future-network services develop.

Taken together, these developments suggest a transition from relatively firm-centred models of telecommunications provision toward more distributed configurations in which value creation depends on relationships among infrastructure providers, network operators, digital platforms, vertical industries, specialised service providers, public actors, and customers. Ecosystems provide the broader structure within which these relationships develop, while platforms, interoperability mechanisms, and resource orchestration support their coordination [28], [30], [31]. The distribution of roles, control, and economic value nevertheless remains dependent on the particular business configuration and the mechanisms through which participants contribute to and benefit from the service. Understanding these relationships provides the basis for examining how technological and ecosystem capabilities are translated into identifiable value propositions, monetisation mechanisms, and commercially deliverable services, which are considered in the following section.

2.5 Value Creation, Monetisation and Service Productisation

The commercial significance of a technological capability depends on whether it can be translated into a recognisable form of value for customers or other stakeholders and, ultimately, into a mechanism through which participating organisations can capture part of that value. These processes should be distinguished analytically. Research on data-driven business models differentiates between the value proposition offered to customers, the technical and organisational architecture supporting its delivery, the network of actors participating in the service, and the financial mechanisms through which revenues are generated [33]. A broader value-oriented perspective similarly distinguishes value propositions from the technological and organisational mechanisms through which value is created, the relationships governing interaction among stakeholders, and the subsequent capture and distribution of that value [34].

Value creation should therefore not be reduced to revenue generation alone. Technology-enabled services can produce economic and organisational benefits, but value may also include technological, social, or public outcomes depending on the actors and context involved [34]. In commercial applications, digital capabilities may contribute to outcomes such as greater efficiency, lower costs, improved availability, increased safety, personalisation, or more informed decision-making [33]. The existence of these benefits can support a value proposition, but it does not by itself demonstrate how the provider will capture revenue from the resulting service.

A further distinction concerns the relationship between technological enablers and the mechanisms through which they generate value. Technical capabilities can provide the underlying conditions for value creation, while value drivers and value-creation processes describe the activities through which those capabilities contribute to useful outcomes and the ways in which resources and actors are combined in practice [34]. Technological functionality should therefore not itself be interpreted as evidence of an economically viable value proposition. Its commercial relevance depends on whether it can address an identifiable customer requirement, organisational objective, or other stakeholder need and whether it can be incorporated into a service through which that value can be delivered.

This distinction is particularly visible in data-intensive services. Connected products can generate substantial volumes of potentially valuable data and enable new service opportunities, while organisations may nevertheless experience difficulty translating those resources into sustainable commercial outcomes [33]. The ability to commercialise a digital resource depends on how it is accessed, processed, incorporated into a defined service, and made available to relevant customers or complementary service providers. Where data remain controlled by a particular infrastructure or

platform owner, third-party service provision may additionally depend on technical gateways, contractual access arrangements, standardised interfaces, or intermediary platforms [33].

Intermediation can itself become a source of value creation. Digital platforms may aggregate heterogeneous resources, harmonise data formats, support secure exchange, manage access, and provide a common interface through which several service providers can obtain the resources required for their own offerings [33]. More generally, multi-actor digital environments can shift value creation from a single organisational value chain toward networks in which complementary resources and capabilities are integrated across several participants [34]. Value creation in such settings is therefore partly relational, depending on how actors cooperate, contribute resources, and coordinate service provision.

Value creation and value capture should nevertheless remain analytically distinct. The creation of useful outcomes does not ensure that the organisation enabling those outcomes will be able to appropriate them financially. In multi-stakeholder systems, value capture concerns how the benefits generated through collective activity are appropriated and distributed among participating actors, while incentives and governance arrangements influence whether continued participation remains attractive to the organisations involved [34]. This issue becomes particularly important where several actors jointly provide data, infrastructure, technological functionality, or service components, since the creation of collective value may require corresponding arrangements for attributing and distributing the resulting economic benefits.

Monetisation can therefore be understood as a more specific aspect of value capture in which an identifiable transaction mechanism converts part of the value associated with a service or resource into revenue. The stakeholder receiving the principal benefit is not necessarily the same stakeholder from whom payment is obtained. Data platforms, for example, may enable data owners to commercialise resources by providing access to independent service providers, while the services subsequently developed can generate additional value for other participants or end users [33]. The revenue mechanism consequently needs to be considered in relation to the wider value proposition, the customer or stakeholder being charged, the resource or service exchanged, and the ecosystem through which delivery occurs rather than being treated as a complete business model in isolation.

The conversion of a technological capability into a commercially consumable service also requires the capability to be organised into a sufficiently defined offering. Access-based product-service systems provide a useful illustration. In these arrangements, consumers obtain access to the use of a product for a fee rather than acquiring ownership, while digital platforms, smartphones, sensors, and connected infrastructure can support activities such as locating resources, reserving and accessing them, processing payments, monitoring their condition, and interacting with the service provider [35]. Digitalisation can therefore make service-based access models more practical by reducing transaction effort and enabling more flexible and convenient service interactions.

The value of such service configurations nevertheless depends on more than their technical availability. Evidence from digitalised access-based services shows that users value characteristics such as convenience, flexibility, time savings, information availability, and perceived control, while failures in applications, connectivity, sensors, or other digital components can disrupt the service itself [35]. This demonstrates that the commercialisation of a digital capability requires attention not only to what the underlying technology can perform but also to how reliably and conveniently that functionality can be incorporated into the customer experience. A technically enabled offering only becomes meaningful as a service when customers can access and use it through sufficiently reliable delivery and interaction mechanisms.

Service productisation can consequently be viewed as an intermediate step between technological capability and monetisation. From this perspective, a technological resource becomes commercially actionable when it is incorporated into a recognisable and repeatable service proposition with identifiable users, access conditions, delivery responsibilities, service characteristics, and an associated mechanism of value capture. Digitalisation can facilitate this transition by enabling resources to be accessed, monitored, configured, and charged for through software-based interfaces and platforms [35], [33]. The precise commercial configuration nevertheless depends on how technological resources, customer value, actor relationships, service delivery, and revenue mechanisms are combined.

Taken together, these perspectives establish a progression from technological capability to value creation, from value creation to a defined service proposition, and from service provision to value capture and monetisation. These stages are related but should not be treated as interchangeable. A technical capability may enable a valuable outcome without constituting a commercial service; a service may create substantial customer or ecosystem value without revealing an explicit revenue mechanism; and an identifiable monetisation mechanism does not by itself establish that the wider business model is economically sustainable [34], [33]. Assessing whether such configurations can be implemented at acceptable cost and generate sustainable economic returns therefore requires appropriate methods of business and techno-economic evaluation, which are considered in the following section.

2.6 Business-Model Evaluation and Techno-Economic Assessment

The identification of a technically feasible service and an associated mechanism of value creation does not by itself establish that the resulting business configuration is economically viable. Future-network services can require substantial infrastructure investment, recurring operational expenditure, coordination between multiple stakeholders, and technical configurations capable of satisfying specific performance requirements. Evaluation is therefore necessary to examine not only whether a proposed service can function technically, but also what resources are required to deliver it and whether alternative implementation choices produce acceptable economic outcomes.

Techno-economic assessment provides one approach for linking these technical and economic dimensions. Rather than treating network architecture and cost as independent considerations, techno-economic methods can combine technical deployment requirements, infrastructure configurations, business-model assumptions, and financial models within a common analytical process. In the context of connected and automated mobility, for example, techno-economic evaluation has been used to identify the relevant service ecosystem and potential business models, estimate the infrastructure required for service provision, calculate its total cost of ownership, and allocate deployment costs among participating stakeholders [36]. Such approaches therefore provide a mechanism for tracing how technical design decisions translate into economic consequences.

A common component of techno-economic modelling is the distinction between capital expenditure and operational expenditure. Capital expenditure represents investment associated with deploying infrastructure and acquiring the resources required for service provision, whereas operational expenditure captures recurring costs associated with operating, maintaining, managing, and supporting the deployed system. These components can be combined within total-cost-of-ownership models to represent the cumulative economic implications of a deployment over a defined planning horizon [36], [37]. Depending on the analytical scope, operational costs may be further differentiated to include elements such as energy consumption, technological support, licensing, and the expected economic consequences of service downtime [38].

The economic outcome of a network deployment can depend strongly on its technical configuration. Alternative levels of infrastructure density, computing placement, bandwidth provision, or network architecture can produce different cost structures while simultaneously supporting different levels of technical performance [36]. A techno-economic methodology can therefore first restrict the analysis to technically feasible alternatives and subsequently compare their economic implications. In industrial 5G-TSN/DetNet environments, candidate designs can first be synthesised and filtered according to latency, jitter, standards, and implementation constraints before their CAPEX, OPEX, and TCO are evaluated [38]. Technical feasibility consequently defines the set of implementable alternatives, but does not determine which of those alternatives is economically preferable.

This relationship also creates the possibility of explicit trade-offs between performance and cost. The lowest-cost configuration may not necessarily provide the most desirable technical characteristics, while achieving more demanding performance requirements can require additional infrastructure, equipment, energy, or operational support. Techno-economic methods can therefore move beyond simple cost comparison toward the joint consideration of technical and economic objectives. Multi-objective approaches can represent alternative designs through cost–performance trade-offs and identify sets of solutions in which improvement in one objective can only be achieved at the expense of another [38]. Such analysis is particularly relevant where several technically acceptable configurations exist but differ substantially in their economic consequences.

The reliability of techno-economic conclusions nevertheless depends on the assumptions incorporated into the model. Equipment prices, infrastructure costs, spectrum-related expenditure, interest rates, investment horizons, network density, and other technical or financial parameters may change over time or remain uncertain during the early stages of technology development. Sensitivity analysis provides a means of examining how strongly the resulting economic estimates depend on these inputs. One-way sensitivity analysis can isolate the influence of individual parameters, while two-way sensitivity analysis can examine the combined influence of related inputs on cost outcomes [37]. Such analysis can also identify the variables that exert the strongest influence on CAPEX, OPEX, or TCO, thereby revealing where technological improvement or cost reduction may have the greatest economic effect.

Scenario-based evaluation provides a complementary means of addressing uncertainty and design alternatives. Rather than assuming a single fixed deployment, models can compare different levels of infrastructure density, resource placement, or architectural configuration and examine how these alternatives affect both service performance and cost [36]. More advanced methodologies can additionally incorporate variation in prices, energy consumption, operating conditions, or downtime risk when ranking technically feasible designs [38]. The resulting estimates should therefore be interpreted as conditional on the assumptions and scenarios examined rather than as deterministic predictions of future commercial performance.

In multi-actor environments, economic evaluation can also extend beyond estimating the aggregate cost of a service. Where infrastructure or resources are shared between network operators, infrastructure providers, service providers, or other ecosystem participants, the distribution of costs among stakeholders can become part of the business-model configuration itself. Cost-allocation models can be used to associate deployment expenditure with the actors participating in a particular service arrangement and to examine how collaborative or shared-infrastructure configurations alter the economic responsibilities of those actors [36]. This further demonstrates that the economic feasibility of a service may depend not only on its total cost but also on how investment, operational responsibility, and economic returns are distributed across the ecosystem.

Technical experimentation provides a different but complementary form of evidence. Testbeds and proof-of-concept environments can be used to integrate network components, deploy virtualised functions, validate interoperability between distributed domains, and trial representative services under controlled conditions. In the 5G-RANGE experimentation environment, for example, physical and network-layer components were integrated through an NFV-based testbed, virtual network functions were deployed and orchestrated, and voice and data services were trialled to verify the operation of the combined technical scenario [39]. Such experimentation can therefore provide evidence that a proposed architecture or service configuration can be implemented and can operate with measurable technical performance.

The evidential meaning of such validation should, however, remain clearly bounded. Successful integration, service delivery, or measured network performance demonstrates aspects of technical feasibility, but it does not by itself establish market demand, customer willingness to pay, sustainable revenues, or profitability. Technical experimentation and business/economic evaluation should therefore be treated as related but distinct dimensions of evidence. A prototype or testbed can reduce uncertainty concerning whether the technology works as intended, while techno-economic or business evaluation addresses different questions concerning the resources required, costs incurred, revenues potentially generated, and commercial attractiveness of the proposition.

Similarly, a detailed techno-economic cost model should not automatically be interpreted as complete validation of a business model. An assessment may provide extensive evidence concerning infrastructure requirements, CAPEX, OPEX, technical performance, and cost sensitivity while leaving demand, pricing, revenue generation, or market adoption outside its analytical scope. The CCAM analysis, for example, explicitly identifies further investigation of revenue models as necessary for completing the business-case evaluation [36]. A technically feasible and cost-efficient implementation therefore provides evidence concerning additional dimensions of implementation beyond a conceptual proposal, but still does not necessarily demonstrate that a sustainable market or profitable business model exists.

Business-model evaluation is consequently best understood as potentially requiring several complementary forms of evidence. Analytical modelling and simulation can examine whether proposed configurations satisfy defined assumptions or performance requirements; experimental environments can demonstrate technical integration and operation; and techno-economic assessment can connect implementation choices to their cost implications [38], [39]. More complete commercial validation may additionally require evidence concerning demand, pricing, revenues, adoption, and actual market behaviour. No single form of technical or economic evidence should therefore automatically be interpreted as demonstrating all dimensions of business-model viability.

Taken together, these approaches illustrate that the evaluation of future-network business propositions can range from technical modelling and experimentation to increasingly integrated forms of techno-economic and business assessment. CAPEX, OPEX, and TCO models provide information about the expenditure associated with different deployment configurations, while scenario comparison, sensitivity analysis, and multi-objective evaluation help examine uncertainty and trade-offs between competing alternatives [37], [38]. Testbeds and proof-of-concept environments provide complementary evidence concerning technical implementation and service operation [39]. These forms of evaluation can substantially strengthen the evidential basis of a proposed business configuration, but their conclusions remain dependent on the scope, assumptions, and dimensions of validity that each method actually examines. Moreover, even a technically feasible and economically promising configuration may encounter institutional, organisational, market, or regulatory conditions that constrain its

implementation. These broader conditions for business-model realisation are considered in the following section.

2.7 Conditions for Business-Model Realisation

The identification of a technically feasible, value-creating, and potentially cost-effective service does not necessarily imply that the corresponding business model can be realised in practice. Implementation depends on a wider set of economic, organisational, technical, and institutional conditions that determine whether the required infrastructure can be financed, whether participating actors can coordinate their activities, whether the underlying service can be operated securely and reliably, and whether the relevant market configuration is permitted within the prevailing regulatory environment. Business-model realisation should therefore be understood as a process in which technological capability must be accompanied by commercially, organisationally, and institutionally viable conditions.

Economic and investment conditions represent one important constraint. Infrastructure-intensive deployments require substantial upfront capital while their commercial attractiveness depends on the size, purchasing power, and adoption behaviour of the addressable market. Evidence from remote-area connectivity illustrates how high investment per covered user can coincide with smaller and more uncertain revenue opportunities, making technically feasible deployments difficult to justify commercially [40]. Recurring operational requirements can further weaken the business case, particularly where maintenance, site access, energy provision, or geographically dispersed infrastructure create additional costs after deployment.

Revenue uncertainty introduces a related investment risk. Expected returns may depend on assumptions concerning customer adoption, service penetration, average revenue per user, and the pace at which demand develops. Where these variables are difficult to estimate, high-CAPEX investments become harder to justify and may be deprioritised in favour of projects offering stronger or more predictable risk-adjusted returns [40]. Commercial realisation consequently depends not only on whether a service can theoretically create value, but also on whether its expected revenue stream is sufficiently credible to support the required investment and continued operation.

Economic constraints can also influence the organisation of the service ecosystem. Where a single provider cannot efficiently support the investment or operational burden, infrastructure sharing, specialised local operators, external financing, or revenue-sharing arrangements may provide alternative implementation structures [40]. Such arrangements can reduce the exposure of individual actors but simultaneously introduce additional requirements concerning funding, contractual coordination, network integration, allocation of responsibilities, and distribution of economic returns. Collaborative models therefore represent both a possible response to economic constraints and a potential source of organisational complexity.

Organisational readiness constitutes a further condition for implementation. The adoption of digitally enabled service models involves more than the acquisition of new technological infrastructure, as transformation can require changes in business processes, organisational structures, workforce capabilities, stakeholder relationships, and mechanisms of value creation and capture [41]. Limited digital literacy, insufficient training, lack of technical experience, and resistance to changes in established roles or working practices can consequently restrict an organisation's ability to operationalise new technological capabilities. Similar concerns have been identified prospectively in discussions of 6G-enabled logistics, including skill shortages, implementation complexity, training requirements, and specialised maintenance needs [42].

Organisational challenges extend beyond the boundaries of individual firms when service provision depends on several stakeholders. Implementation can require alignment between actors with different objectives, resources, incentives, and expectations concerning the benefits of digital transformation. Collaboration, information sharing, formal coordination mechanisms, and mutual trust can therefore become important conditions for collective implementation [41]. Information sharing may be particularly difficult where individual actors perceive commercially sensitive data or information asymmetries as sources of bargaining power or competitive advantage.

The distribution of costs and benefits can further influence stakeholder participation. Even where transformation creates value for the ecosystem collectively, individual actors may have weak incentives to cooperate if they bear substantial investment, operational, or organisational costs without receiving a corresponding share of the expected benefits [40], [41]. Governance arrangements must therefore address not only technical coordination but also the allocation of responsibilities, investments, information, and economic returns across participating organisations.

Implementation may additionally require the integration of new technologies with established processes, infrastructures, and legacy systems. Interoperability in such environments is therefore both a technical and an organisational concern because previously separate actors, systems, and workflows may need to operate as part of a common service environment [41]. Leadership, strategic alignment, workforce development, and readiness for change can help organisations manage this transition, but their importance is likely to vary with organisational size, technological maturity, sectoral context, and the complexity of the surrounding ecosystem.

Technical realisation also requires increasingly virtualised and multi-tenant service environments to operate securely and reliably. Technologies such as MEC, SDN, NFV, and network slicing make network resources more programmable and shareable, but they also introduce shared infrastructures, virtualised functions, programmable interfaces, and additional dependencies between service providers and users [43]. Weak isolation, insecure interfaces, inconsistent security policies, or inadequate identity and access management can affect not only an individual network component but also other services and organisations relying on the same technical environment.

These risks become more difficult to manage when service provision is distributed across several organisations. The stakeholder experiencing the consequences of a security incident may differ from the organisation responsible for the vulnerable infrastructure or service component. Furthermore, the allocation of responsibility can change according to the business-model configuration because different service arrangements distribute control over infrastructure, applications, data, and user access differently among operators, tenants, intermediaries, and customers [43]. Security should therefore not be treated solely as a technical characteristic of the network. In multi-stakeholder environments, practical security also depends on trust relationships, governance arrangements, responsibility allocation, and coordination across organisational boundaries.

Regulatory and institutional conditions constitute an additional layer of business-model realisation because they define the boundaries within which network actors are permitted to deploy infrastructure, access resources, provide services, and interact with other market participants. In the European local-network context, emerging 5G and prospective 6G configurations challenge regulatory arrangements that were largely developed around nationwide MNO-centred models [44]. As local and specialised providers enter the ecosystem, uncertainty concerning their regulatory classification, rights, and obligations can consequently affect whether proposed operating models can be implemented and scaled.

Spectrum management represents a particularly important example of this relationship. Local network deployment depends on access to suitable spectrum, while traditional spectrum-assignment mechanisms have predominantly been structured around wide-area mobile operators. For non-MNO actors, timely and affordable access to locally usable spectrum can therefore affect market entry and deployment feasibility [44]. Regulatory conditions concerning access, interconnection, and interoperability are similarly relevant because local networks may need to connect with other operator networks and infrastructures to provide end-to-end services.

Regulation also interacts with security, privacy, data governance, and competition. Multi-stakeholder environments create questions concerning data ownership, confidentiality, personal-data protection, cybersecurity responsibilities, market power, pricing, and the conditions under which incumbent and emerging actors compete or collaborate [44]. These issues demonstrate that regulatory feasibility cannot always be separated cleanly from technological architecture or business-model design. Rules governing spectrum or infrastructure access can alter deployment choices and associated costs, while privacy, security, and competition requirements can influence the responsibilities and incentives of ecosystem participants.

More broadly, the conditions affecting business-model realisation are interconnected rather than independent. High infrastructure costs may encourage sharing arrangements, but such arrangements introduce new requirements for governance, security, and responsibility allocation [40], [43]. Spectrum or access regulation can influence which actors are permitted to deploy infrastructure and therefore alter both ecosystem structure and investment economics [44]. Similarly, the introduction of increasingly sophisticated technologies may require additional skills, maintenance capabilities, security measures, and organisational adaptation [41], [42]. A barrier originating in one domain can therefore generate consequences in several others.

Taken together, these conditions indicate that the realisation of future-network business models cannot be assessed solely through technological feasibility or anticipated value creation. Sustainable implementation also requires an investment structure capable of supporting deployment and operation, organisational capabilities appropriate to the new service environment, coordination and trust among participating stakeholders, technically secure and interoperable systems, and regulatory conditions that permit the proposed roles and transactions to develop. The relative importance of these conditions will vary across services, markets, and jurisdictions, particularly as direct evidence concerning commercially deployed 6G systems remains limited. They nevertheless provide the broader realisation context within which the technological, commercial, and ecosystem opportunities discussed in the preceding sections must ultimately be interpreted.

2.8 Chapter Synthesis

The transition from 5G through B5G toward 6G reflects more than a progression in network performance. It is also associated with a broader shift toward increasingly programmable, virtualised, distributed, and service-oriented network environments in which infrastructure capabilities can be configured, exposed, and combined in more flexible ways. Developments such as network slicing, edge and cloud integration, software-defined networking, virtualisation, and deeper integration of artificial intelligence expand the range of technical resources that can potentially be organised into differentiated services. Their business relevance, however, depends on how these capabilities are incorporated into commercially meaningful configurations rather than on technological functionality alone.

This transition places business-model innovation within a wider ecosystem context. Future-network services are increasingly likely to depend on interactions among network operators, infrastructure providers, vertical industries, platform actors, specialised service providers, and other stakeholders whose resources and capabilities contribute jointly to service delivery. As a result, value creation may take place across multi-actor networks rather than within a single organisational value chain. The emergence of platform-based arrangements, local and specialised operators, shared infrastructures, and service-oriented configurations further illustrates how technological change can alter the distribution of roles, responsibilities, and opportunities for value creation and capture.

A central implication of this background is that technological capability, value creation, service provision, and monetisation should remain analytically distinct. A network capability may enable improved efficiency, customisation, flexibility, or access to new resources without necessarily constituting a clearly defined commercial service. Similarly, a service may generate value for customers or ecosystem participants without revealing how that value will be captured financially. The commercialisation of future-network capabilities therefore depends on their translation into sufficiently defined service propositions, supported by identifiable mechanisms of delivery, access, pricing, and value capture.

The credibility of such propositions also depends on how they are evaluated and under what conditions they can be implemented. Technical modelling, simulation, experimentation, and testbeds can provide evidence concerning feasibility and performance, while techno-economic and business evaluation can examine infrastructure requirements, costs, investment implications, and other dimensions of economic viability. These forms of evidence are complementary but not interchangeable. Even where a configuration is technically feasible and economically promising, its realisation may still depend on organisational capabilities, stakeholder coordination, investment incentives, security and interoperability, and regulatory or institutional conditions.

Taken together, the preceding sections establish the conceptual basis for examining emerging 6G business models as part of an evolutionary and multi-dimensional transition rather than as an isolated technological development. This perspective informs the systematic literature review undertaken in the following chapter. It provides the foundation for distinguishing the business-model configurations proposed across 5G, B5G, and 6G; examining how technical enablers are linked to value creation and monetisation; assessing the methodological and evidential approaches used to evaluate these propositions; and identifying the conditions that may constrain their practical realisation.

3. Systematic Literature Review Methodology

3.1 Review Design and Preliminary Scoping

This study adopts a Systematic Literature Review (SLR) methodology informed by the PRISMA 2020 framework, which was used to support transparent reporting of the identification, screening, and inclusion of publications. The review was organized into sequential stages comprising preliminary scoping, systematic searching, deduplication and relevance screening, formation of a common review corpus, and subsequent RQ-specific reassessment and analysis.

An initial scoping stage was undertaken to identify the core concepts, recurring terminology, and principal thematic areas associated with business models and the techno-economic dimensions of 5G, B5G, and 6G networks. This exploratory stage informed the preliminary formulation of the research questions and the construction of the search strategy. The research questions established the conceptual direction of the review from the outset, while their analytical boundaries and evidence requirements were subsequently refined and operationalized following examination of the literature retrieved through the systematic search. This approach enabled the review to retain a consistent overall research focus while defining evidential requirements appropriate to the specific purpose of each research question.

3.2 Search strategy and information sources

The systematic search was conducted across six scholarly databases and publisher/digital-library platforms: IEEE Xplore, ACM Digital Library, SpringerLink, Wiley Online Library, ScienceDirect (Elsevier), and MDPI. The selected sources provided broad coverage of telecommunications, engineering, computing, and interdisciplinary research relevant to 5G- and 6G-related business models and techno-economic analysis. The systematic searches were supplemented by six seed papers identified separately and subsequently subjected to the same study-selection criteria as the records retrieved through the systematic search.

The searches used predefined combinations of terms applied to publication titles and abstracts within a chronological scope from 1 January 2020 to 31 May 2026. The final search and update of the review corpus were completed on 31 May 2026. The following search eligibility parameters were applied:

Search Eligibility Parameters

- **SEP1:** Publication date between 1 January 2020 and 31 May 2026.
- **SEP2:** Publication written in English.
- **SEP3:** The specified search terms were matched against the title and/or abstract fields.
- **SEP4:** The publication was retrieved through one of the selected scholarly databases or publisher/digital-library platforms.

The following six search queries were applied:

- **Query [1] - "Business model" AND 6G**
- **Query [2] - "Business model" AND 5G**
- **Query [3] - "techno-economic" AND 6G**
- **Query [4] - "techno-economic" AND 5G**
- **Query [5] - "Business model" AND 5G AND survey**
- **Query [6] - "Business model" AND 6G AND survey**

Table 3.1: Search queries and raw retrieval counts across the selected information sources.

Systematic Literature Review (SLR)							
Search Query (Title/Abstract, 01.01.2020– 31.05.2026)	IEEE	ACM	Springer	Wiley	ScienceDirect (Elsevier)	MDPI	Total
"Business model" AND 6G	16	10	57	1	11	86	181
"Business model" AND 5G	63	32	340	9	45	86	575
"techno-economic" AND 6G	12	3	22	0	0	140	177
"techno-economic" AND 5G	28	19	48	2	12	140	249
"business model" AND 5G AND survey	2	13	132	4	5	7	163
"business model" AND 6G AND survey	1	4	27	4	1	7	44
Total Results	122	81	626	20	74	466	1389

The resulting raw retrieval counts are presented in Table 3.1.

Note: Search-result counts represent raw records retrieved before deduplication and may therefore overlap across information sources. Six seed papers were identified separately and are therefore reported only in the aggregate total rather than against individual search queries. (1,389 systematic-search records + 6 supplementary seed records = 1,395 raw records)

The systematic search covered six scholarly databases and publisher/digital-library platforms: IEEE Xplore, ACM Digital Library, SpringerLink, ScienceDirect (Elsevier), Wiley Online Library, and MDPI. The searches used six predefined combinations of terms centred on business models, techno-economic analysis, 5G, 6G, and survey literature. Only English-language publications within the defined review period were considered.

3.3 Deduplication and Screening Process

Following completion of the systematic search, the retrieved records were subjected to deduplication and relevance screening. Duplicate publications retrieved through multiple queries or information sources were removed before screening. Of the 1,395 raw records identified through the

database/platform searches and supplementary seed sources, 359 duplicate records were removed, leaving 1,036 unique records for relevance screening.

The remaining records were screened primarily on the basis of their titles and abstracts against the study-selection criteria described in Section 3.4. Where the relevance of a publication could not be determined with sufficient confidence from the abstract alone, targeted inspection of the full text was undertaken to clarify the study focus and its potential relevance to the review. This supplementary inspection supported the screening decision and was not treated as a separate systematic full-text eligibility stage.

The screening process examined whether publications contributed substantively to one or more areas relevant to the scope of the review, including 5G- or 6G-related business models and business ecosystems; value-creation, revenue, or monetisation mechanisms; technical enablers associated with new business opportunities or value propositions; methods used to analyse or evaluate business-model propositions; and barriers, risks, or implementation challenges affecting their realisation. Of the 1,036 records screened, 818 were excluded as unrelated or outside the defined review scope, resulting in 218 publications retained in the common review corpus.

Following completion of the systematic search and common-corpus screening, the four research questions introduced in Chapter 1 were further operationalised into RQ-specific analytical boundaries and evidence requirements. The research questions provided the conceptual direction of the review, while examination of the retrieved literature enabled the analytical criteria and evidential thresholds applied to each RQ to be defined more precisely. Inclusion in the common review corpus therefore did not imply automatic inclusion in every RQ-specific analysis. These procedures are described in detail in Section 3.5. The overall study-selection process is summarised in Figure 3.1.

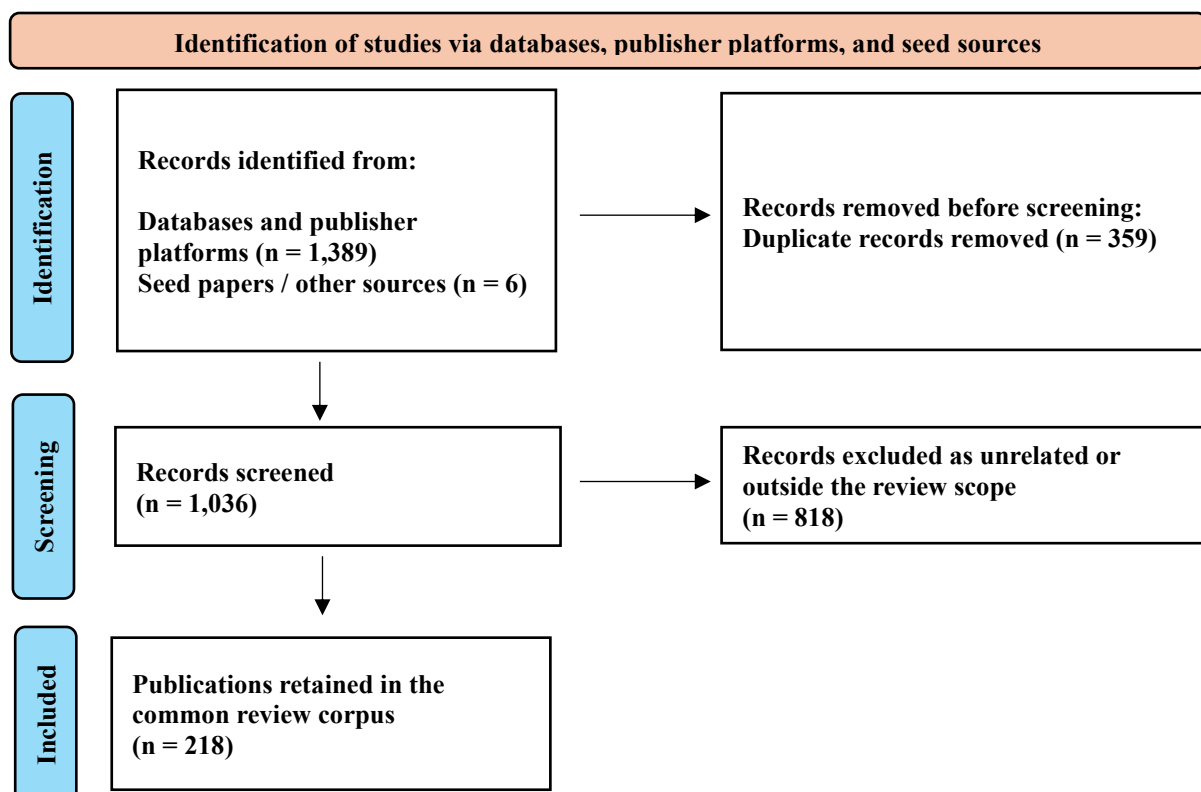


Figure 3.1: Study-selection flow adapted from the PRISMA 2020 framework.

Note: The search covered publications from 1 January 2020 to 31 May 2026. Screening was conducted primarily on the basis of titles and abstracts, with selective full-text inspection where abstract-level information was insufficient to determine relevance. This supplementary inspection was not treated as a separate systematic full-text eligibility stage. The 218 retained publications formed the common review corpus and were subsequently reassessed according to the analytical requirements of each research question.

3.4 Study selection criteria and Formation of the Common Corpus

Study Selection Criteria (IC)

- **IC1:** The study investigates business models, business ecosystems, value creation mechanisms, revenue models, monetisation mechanisms, governance models, or market structures related to 5G, B5G, or 6G networks and their evolution.
- **IC2:** The study discusses or evaluates technical enablers of 5G, B5G, or 6G and explicitly links them to business opportunities, service innovation, value propositions, or revenue generation (e.g., network slicing, AI-native networks, edge-cloud continuum, integrated sensing and communication, private networks, digital twins, network programmability).
- **IC3:** The study proposes, analyses, evaluates, validates, or compares business-model propositions using a clearly identifiable methodological approach (e.g., simulation, techno-economic modelling, case studies, expert interviews, surveys, conceptual frameworks, or qualitative analysis).
- **IC4:** The study identifies or discusses barriers, risks, adoption challenges or implementation constraints of 5G, B5G, or 6G business models (e.g., regulatory barriers, CAPEX/OPEX issues, standardisation challenges, organisational readiness, spectrum access, ecosystem maturity).
- **IC5:** The study provides insights relevant to the evolution from 5G business models toward 6G business models (e.g., private 5G, MVNO, Network-as-a-Service, Slice-as-a-Service, infrastructure sharing, micro-operators).

A publication was eligible for inclusion in the common review corpus when it satisfied at least one of the substantive inclusion criteria (IC1–IC5), provided that none of the exclusion criteria applied. The inclusion criteria were therefore not cumulative requirements. Because the common corpus was designed to support multiple research questions, publications could enter the review through different forms of substantive relevance and were subsequently reassessed independently against the analytical requirements of each RQ.

Studies meeting at least one inclusion criterion were subsequently assessed against the exclusion criteria. A publication was excluded when any of the following criteria applied:

Exclusion Criteria (EC)

- **EC1:** Pure Technical Studies: The study focuses exclusively on technical implementation, algorithms, protocols or performance optimization without discussing business implications, value creation or economic aspects.
- **EC2:** Application-Domain Studies Outside Scope: The study focuses on sector-specific applications without linking them to telecommunications business models or techno-economic considerations.

- **EC3:** — General Technology Surveys Without Business Perspective: The study provides only a general overview of technologies without discussing business models, monetisation, governance or economic implications.
- **EC4:** Social, Political or Geopolitical Studies: Studies without direct relevance to telecommunications business models.
- **EC5:** Non-substantive Contributions: The publication does not provide sufficient substantive content to support evidence extraction against any of the inclusion criteria.
- **EC6:** No Relevant Connection to 5G, B5G, or 6G: The publication has no substantive connection to mobile-network business models, ecosystems, techno-economic considerations, or the transition toward future network generations.

No single formal risk-of-bias or standardized study-quality scoring instrument was applied across the complete corpus because the review included heterogeneous research designs, including conceptual, qualitative, empirical, simulation-based, and techno-economic studies for which a single appraisal instrument would not provide a meaningful common measure. Instead, methodological confidence was supported through predefined eligibility rules, source-level verification, conservative evidence-attribution procedures, explicit consideration of evidence provenance and maturity where relevant, and targeted re-examination of ambiguous or higher-risk cases.

3.5 RQ-Specific Analytical Procedures

Following formation of the common review corpus, the 218 retained publications were reassessed separately for relevance to each research question. Inclusion in the common corpus did not imply automatic inclusion in every RQ-specific analysis. Instead, each research question applied its own analytical boundary, unit of analysis, and evidential threshold according to the type of claim being examined. This approach enabled a common underlying literature base to be retained while avoiding the application of a single evidential rule to substantively different research questions.

3.5.1 RQ1: Business-Model Archetype Analysis

RQ1 examined the business-model archetypes proposed or studied in relation to 6G and the broader transition from 5G through B5G to 6G. Given the comparatively early stage of 6G development, the analysis adopted an evolutionary perspective rather than assuming the existence of a mature and independent 6G business-model landscape. Evidence from earlier network generations was therefore retained where it provided relevant commercial or organisational antecedents, while generation-specific classification was used to distinguish precursor evidence from direct 6G-oriented evidence.

Each publication in the common review corpus was reassessed for substantive business-model evidence relevant to the mobile-network or network-enabled service ecosystem. Inclusion in the RQ1 synthesis did not require empirical evaluation, quantitative modelling, or demonstrated commercial deployment, since conceptual and prospective studies could still provide substantive evidence concerning proposed business-model configurations. However, generic references to business potential, commercial opportunity, or business models were insufficient. Relevant evidence had to articulate at least one meaningful business-model component, such as stakeholder roles, value propositions, value creation or capture, pricing or revenue mechanisms, service provision, ownership or access arrangements, marketplace exchange, data monetisation, or infrastructure and resource sharing.

The analytical boundary focused on the mobile-network or network-enabled service ecosystem itself. Downstream sectoral business models that merely used 5G or 6G connectivity as an enabling technology were not treated as primary RQ1 evidence unless the network or service configuration constituted a substantive element of the business model. Publications were consequently classified as primary, adjacent, or excluded for RQ1. Primary publications contained substantive network- or service-level business-model evidence and entered the archetype synthesis. Adjacent publications contained meaningful but peripheral or downstream evidence and were retained for boundary and robustness purposes but excluded from primary frequency calculations. Publications without sufficient RQ1 evidence were excluded from the RQ1-specific synthesis.

The publication constituted the principal unit of analysis. Each primary publication was additionally classified according to its generation role as 5G precursor, B5G transition, direct 6G, or cross-generation. This classification was used to prevent 5G evidence from being interpreted as direct confirmation of 6G business-model development and to distinguish established commercial structures from more forward-looking configurations.

Business-model archetypes were developed using a hybrid-inductive coding approach. Concepts already prominent in the research question and the literature, including Network-as-a-Service, platform-oriented models, Slice-as-a-Service, and infrastructure sharing, were treated as sensitising categories rather than as a predetermined exhaustive taxonomy. Additional configurations were allowed to emerge during source-level coding. Terminological variants were subsequently consolidated where they represented the same underlying business-model logic, whereas recurrent configurations exhibiting substantively distinct value-creation, governance, service-provision, or transaction logics were retained separately.

Archetype coding was multi-label rather than mutually exclusive. A publication could therefore be assigned to more than one archetype where multiple substantive business-model configurations were supported by the source. Descriptive analysis was subsequently used to examine publication frequencies, proportions, and generation-specific distributions; no inferential statistical testing was applied.

Following development of the archetype taxonomy, a second interpretive layer was used to examine evolutionary positioning across network generations. Archetypes were synthesised into the broader categories 5G-established/inherited, cross-generational/evolving core, and 6G-emergent according to the generational distribution of their supporting evidence. These categories did not constitute a second business-model taxonomy but an interpretive synthesis of the underlying archetypes. Because both archetype coding and evolutionary positioning could overlap within individual publications, additional comparisons were conducted at unique-publication level to avoid double counting.

3.5.2 RQ2: Technical Enabler–Value Linkage Analysis

RQ2 examined how technical enablers associated with the evolution from 5G through B5G toward 6G were linked to identifiable value propositions, broader business or economic value, and mechanisms of value capture. The analysis was conducted as a structured qualitative evidence synthesis complemented by descriptive quantitative analysis. Its purpose was not simply to identify publications in which technical and business terminology co-occurred, but to determine whether a sufficiently traceable relationship could be established between a specific technical enabler, the capability enabled by that technology, and a subsequent value proposition, business impact, or monetisation mechanism.

The principal analytical pathway was defined as:

Technical Enabler → Technical Capability → Value Proposition / Business Impact → Monetisation or Economic Value

For evidence concerning direct value capture, a more specific attribution pathway was applied:

Technical Enabler → Capability → Productisation → Service or Resource Offered → Pricing / Transaction Mechanism → Revenue or Value Capture

These pathways were used as an analytical attribution framework rather than as a form of causal identification. Their purpose was to prevent economic or monetisation outcomes from being attributed to a technical enabler solely because the technology and the business outcome appeared within the same publication or architectural configuration.

The principal unit of analysis was the paper-technical-enabler relationship. A publication could therefore contribute evidence for more than one technical enabler where each relationship was independently supported by the source. Repeated passages concerning the same enabler within the same publication were not counted as separate analytical relationships. Source passages were instead used as evidence anchors to locate and verify the underlying evidence. These anchors functioned as retrieval and validation points rather than as the quantitative unit of analysis, and final classifications were based on examination of the original publication and the surrounding textual context.

Because terminology varied considerably across the literature, technical concepts were normalised into a consistent enabler ontology before cross-publication synthesis. Categories included established and emerging network technologies such as Network Slicing, NFV, SDN, MEC/Edge Computing, cloud-native architectures, Network Softwarisation, Network Orchestration, Open RAN, NTN, Massive MIMO, mmWave, heterogeneous networks, small-cell and ultra-dense configurations, spectrum sharing, THz communications, reconfigurable intelligent surfaces, and AI/ML-enabled networking. Emerging concepts were retained separately where the available evidence supported a substantively distinct technical category. Technical enablers were distinguished from service classes, deployment configurations, and business-model constructs; for example, service categories such as eMBB, URLLC, and mMTC and commercial constructs such as private networks or “as-a-Service” models were not automatically treated as technical enablers.

Positive evidence was classified according to the specificity with which economic value could be attributed to the focal technical enabler. Two principal positive evidence classes were used. Direct monetisation evidence required an explicit and enabler-attributable transaction or pricing mechanism, such as leasing, subscription, usage- or unit-based charging, SLA or premium-linked charging, wholesale access, marketplace or auction-based resource trading, licensing, or implementation fees. A numerical tariff was not required, but generic statements that a technology could generate revenue or be monetised were insufficient unless an identifiable mechanism of value capture was also specified. Business/economic value evidence was assigned where the enabler could be linked to an identifiable economic or business outcome, such as CAPEX/OPEX reduction, improved resource efficiency, flexibility, scalability, service differentiation, market enablement, automation, or improved economic viability, but no sufficiently specific transaction mechanism was present.

A third category was retained for contextual or insufficiently attributable evidence. This included cases in which an economic mechanism was present but could not be defensibly assigned to the focal technical enabler, or where the relevant value-capture mechanism belonged more directly to another architectural component, platform, or business actor. Such cases were retained for transparency and boundary checking but were excluded from the positive synthesis. Where no usable relationship between a

technical enabler and value proposition, economic impact, or monetisation mechanism could be established, the relationship was excluded from the retained analytical evidence base.

A strict enabler-level attribution rule was applied throughout. Co-occurrence alone was not sufficient for classification. Where several technologies appeared within the same architecture, economic or monetisation evidence was assigned only to the enabler for which the relationship could be supported directly from the source. Whole-system indicators such as ROI, NPV, or TCO were similarly not transferred automatically to every technology contained within a bundled architecture. Attribution required sufficient evidence that the contribution of the focal enabler could be distinguished from the wider technical or business configuration.

Specific decision rules were also applied to recurring commercial terminology. An “as-a-Service” designation was treated as evidence of service configuration rather than direct monetisation unless an associated payment mechanism was explicitly stated. Similarly, the presence of an SLA was not treated as evidence of SLA-based charging unless the source linked the service-level commitment to a premium, charge, penalty, refund, or other financial mechanism. The term “on-demand” was interpreted as evidence of flexible provisioning rather than on-demand pricing unless the publication also specified an associated transaction mechanism. These rules were intended to minimise the risk of inferring commercial meaning from terminology that could refer exclusively to technical or service-provision characteristics.

For each positive paper-technical-enabler relationship, a primary value proposition was coded according to the most immediate value produced by the focal technical capability rather than a more distant downstream business consequence. The coding framework distinguished propositions relating to differentiated or customisable services, performance and service reliability, coverage extension, flexible or on-demand provisioning, cost-efficient infrastructure and operations, new-service or market enablement, open or shared ecosystem participation, autonomous or adaptive network operations, and energy-efficient or sustainable networking. Value propositions were coded separately from monetisation mechanisms in order to preserve the distinction between value creation and value capture.

Direct-monetisation relationships were additionally classified according to their primary monetisation mechanism. The coding framework included lease/rental/wholesale access, usage or unit-based pricing, subscription or recurring fees, SLA/premium/tiered charging, marketplace or auction-based resource trading, licensing or software fees, one-time implementation charges, revenue-sharing or commission arrangements, sponsorship/freemium/bundling, and generic service charging. Where more than one explicit mechanism was present, supplementary mechanisms could be retained as secondary tags while the most direct and distinctive enabler-attributable mechanism was used as the primary classification.

Each positive relationship was also classified by technological generation as 5G precursor, B5G transition, 6G-oriented, or cross-generation. Earlier-generation evidence was retained because several technical enablers expected to remain relevant in 6G already exhibit identifiable value-creation or monetisation mechanisms in 5G and B5G settings. This classification did not assume that a commercial mechanism identified in 5G would persist unchanged in 6G; rather, it enabled comparison of how business value and value-capture mechanisms were articulated across successive stages of network development.

Evidence provenance and maturity were considered during interpretation. The reviewed literature included empirical studies, techno-economic models, conceptual and foresight research, industry-oriented cases, and secondary studies. Prospective evidence was therefore described using terms such

as proposed, anticipated, modelled, or associated with, rather than being interpreted as realised commercial performance. Secondary literature could contribute enabler-specific evidence where attribution was sufficiently clear, but it was not treated as an independent replication of the underlying primary evidence.

Initial evidence mapping and structured search procedures were used to organise the corpus and identify potentially relevant technical–business relationships. Final classifications were based on manual source-level verification of the original publications. Relevant passages were examined in context, ambiguous relationships were re-examined using additional sections of the same source, and targeted within-document searches were used where necessary to locate supporting technical and business terminology. Keyword occurrence itself was not treated as evidence.

A conservative decision principle was applied throughout the RQ2 analysis. Where more than one classification was plausible, the less assertive interpretation was preferred. Ambiguous monetisation evidence was generally retained as broader business/economic value rather than direct monetisation, while unresolved enabler attribution was treated as contextual rather than positive evidence. The objective was therefore to retain only those technical-business relationships that could be defended directly from the underlying source material.

Following validation, the analysis was synthesised across four principal dimensions: technical enabler, value proposition, monetisation mechanism, and technological generation. Descriptive frequencies and cross-tabulations were used to examine recurring relationships and pathways within the reviewed literature. Quantitative counts were interpreted as distributions of evidence within the corpus rather than as measures of market size, causal effect, realised revenue, commercial adoption, or the intrinsic importance of individual technologies.

3.5.3 RQ3: Methodological and Validation Analysis

RQ3 examined the methodological approaches and validation strategies used to evaluate 5G- and 6G-related business-model propositions and compared how these approaches differed across technological generations. The analysis focused specifically on studies containing a substantive business, economic, value-network, commercial, or service-architecture configuration rather than treating any technical assessment conducted in a telecommunications context as business-model evaluation.

Each publication in the common review corpus was reassessed against an RQ3-specific analytical boundary. A study was retained where it examined a substantive 5G-, B5G-, or 6G-related business-model, value-network, economic, commercial, or service-architecture object and either employed an identifiable methodological approach for analysing or evaluating that object or explicitly presented the business proposition at a conceptual stage without an executed evaluation. This distinction enabled both evaluated and prospective business-model research to be represented while preserving differences in evidential maturity.

Studies were excluded where the business dimension was only contextual or incidental to a predominantly technical contribution. Technical assessments of network architectures, radio systems, resource-allocation mechanisms, testbeds, or supporting infrastructure were therefore not treated as business-model evaluation unless a substantive business or economic configuration was itself an object of analysis. Similarly, the presence of CAPEX, OPEX, TCO, cost, ROI, or related economic indicators did not automatically qualify a study where those measures were used solely to compare engineering or infrastructure alternatives. This boundary reflected the distinction between technical feasibility and business-model viability.

The principal unit of analysis was the publication, with each included study constituting one methodological observation. Screening and coding were supported by targeted full-text source review. Initial examination focused on the abstract, introduction, stated research questions or contributions, conclusions, limitations, and targeted searches for methodological and business-related terminology. For potentially eligible studies, the methods, results, discussion, and relevant business or economic sections were examined in greater depth. Keyword searches were used as retrieval aids only; coding decisions were based on the surrounding methodological context and the actual object being analysed.

Each included publication was classified by technological generation as 5G precursor, B5G transition, 6G-oriented, or cross-generation. The main comparative analysis focused on the 5G and 6G-oriented categories, while B5G-transition and cross-generation publications were retained as separate bridge categories rather than reassigned to either generation. This preserved the transitional character of the literature and avoided treating intermediate or explicitly cross-generational studies as direct evidence for only one technological generation.

Each publication was assigned one primary methodological approach. Four mutually exclusive categories were used. Quantitative studies relied predominantly on numerical, mathematical, statistical, optimisation, simulation-based, or techno-economic analysis. Qualitative studies relied primarily on qualitative empirical or interpretive evidence, including interviews, workshops, qualitative case material, or documentary analysis. Mixed-methods studies substantively integrated qualitative and quantitative evidence within the same analytical design. Conceptual-analytical studies developed or analysed business-model structures, scenarios, ecosystems, value networks, or commercial configurations without constituting either a primarily quantitative analysis or an empirical qualitative study. Narrative presentation alone was therefore not sufficient for classification as qualitative research.

The specific evaluation strategies used within each study were coded separately from the overarching methodological approach. This dimension was multi-label because a publication could employ several analytical strategies. The coding framework included techno-economic modelling; simulation or numerical analysis; case study; prototype, testbed, or proof-of-concept; field trial or real deployment; survey; interviews or expert input; empirical statistical analysis; scenario analysis; business-model or value-network analysis; comparative analysis; evidence synthesis or document analysis; text mining or topic modelling; and regulatory or policy analysis. Where a study developed a substantive business-model proposition without executing an identifiable evaluation, the absence of executed evaluation was recorded separately rather than treated as an evaluation strategy.

A further multi-label dimension captured the evaluation target, distinguishing what aspect of the business proposition was being examined from the method used to examine it. The coded targets included business-model structure, economic viability, CAPEX/OPEX/TCO, revenue and profitability, pricing and resource allocation, market acceptance or demand, stakeholder and value-network configuration, technical feasibility supporting the business model, and value capture or monetisation. Separating evaluation strategies from evaluation targets prevented methodological designs from being conflated with the outcomes or quantities they assessed.

Business/economic evidence maturity was coded independently using six ordered categories. Conceptual only represented propositions developed or discussed without executed business or economic evaluation. Analytically modelled referred to propositions examined through mathematical, financial, optimisation, or related formal models. Simulated represented cases in which business or economic outcomes were examined through executed simulation or numerical experimentation. Case-based referred to applied analysis within a substantive case setting without meeting the threshold for

broader empirical assessment. Empirically assessed referred to studies using observed, collected, or systematically analysed empirical business or market evidence. Experimentally demonstrated was reserved for cases in which the business or economic mechanism itself was executed or directly tested, such as actual pricing, transactions, service uptake, compensation mechanisms, or commercial operation.

Technical evidence was coded as a separate dimension using five levels: no primary technical evidence, analytical model, simulation, prototype/testbed, and field trial or deployment. Technical prototypes, simulations, or testbeds therefore did not automatically increase the business/economic maturity classification. This separation was maintained throughout the analysis to avoid treating technical demonstration as equivalent to validation of pricing, demand, profitability, value capture, or commercial viability.

The final RQ3 synthesis combined structured qualitative methodological analysis with descriptive quantitative comparison. Frequencies and percentages were calculated for methodological approaches, evaluation strategies, evaluation targets, business/economic maturity, and technical evidence. Because the numbers of studies differed between technological generations, direct comparison between 5G and 6G was based primarily on within-generation percentages rather than raw frequencies. Multi-label evaluation strategies and evaluation targets were calculated independently and were therefore not expected to sum to 100%.

The analysis was descriptive and comparative rather than inferential. No statistical significance testing was applied because the objective was to characterise the methodological composition and evidential profiles of the reviewed literature rather than to estimate population parameters or causal effects. Following source review, coding reconciliation, and consistency checking, the RQ3 coding dataset was frozen before the final descriptive comparison was conducted.

3.5.4 RQ4: Barrier and Challenge Analysis

RQ4 examined the barriers, risks, and open challenges that may hinder the realisation of proposed business models for 6G and related future mobile-network configurations. The analysis considered four broad domains specified by the research question: technical, economic/commercial, organisational/ecosystem, and regulatory/institutional barriers. The purpose was not to catalogue generic future-network research challenges, but to identify obstacles for which a sufficiently defensible connection could be established with business-model implementation, commercial viability, service delivery, investment, value capture, or ecosystem operation.

Each publication in the common review corpus was reassessed for substantive evidence of a barrier, risk, or unresolved challenge and for whether the identified issue could be linked to a relevant business-model consequence. The analytical logic was expressed as:

Barrier / Risk / Open Challenge → Mechanism → Business-Model Consequence

This pathway was used as an attribution framework rather than as a claim of causal identification. Relevant business-model consequences included reduced investment viability, uncertainty concerning profitability or payback, difficulties in commercialisation or market adoption, failure to satisfy contractual or service-level requirements, constraints on value creation or capture, ecosystem-coordination problems, and regulatory restrictions affecting market entry or service provision.

Particular care was applied to technical evidence. Generic limitations relating to performance, latency, orchestration, interoperability, spectrum, security, energy consumption, or other engineering challenges

were not automatically classified as RQ4 barriers. Such evidence was retained only where the source established a sufficiently clear relationship between the technical issue and a business-model consequence, such as additional deployment or operating cost, reduced scalability, contractual risk, impaired service reliability, lower adoption potential, increased investment uncertainty, or limitations to monetisation. This boundary was intended to prevent the RQ4 synthesis from being inflated by technical challenges without a substantive commercial or organisational implication.

Publications were classified as primary, supporting/contextual, or excluded for RQ4. Primary publications contained sufficiently attributable evidence linking one or more barriers to the realisation of a mobile-network business model, service configuration, investment case, or ecosystem arrangement and entered the core synthesis. Supporting or contextual publications contained relevant future-network challenges but only an indirect or peripheral business-model connection and were retained for boundary and interpretive purposes rather than primary frequency analysis. Publications containing only generic technical limitations or barriers centred on unrelated downstream sectoral business models were excluded from the RQ4-specific synthesis.

The principal unit of analysis was the paper-barrier relationship. Barrier coding was multi-label because a single publication could identify several substantively distinct obstacles. Repeated discussion of the same barrier within one publication was counted only once for that paper-barrier relationship, whereas different barriers identified within the same publication were coded separately. Publication-level prevalence was subsequently used to determine how widely barrier domains and themes occurred across the RQ4 evidence base.

The initial coding framework comprised the four broad RQ4 domains—technical, economic/commercial, organisational/ecosystem, and regulatory/institutional—together with more specific canonical barrier categories within each domain. Individual barriers were normalised into these canonical categories in order to consolidate terminological variants across publications while retaining substantively distinct mechanisms separately.

Following canonical coding, a second interpretive layer was developed to examine recurring patterns that extended across the original domains. These higher-order themes captured broader realisation problems such as investment and economic viability, ecosystem coordination and governance, monetisation and market formation, technical service realisation, regulatory and institutional feasibility, security/privacy/sustainability constraints, and organisational capabilities and legacy transformation. The higher-order themes represented an interpretive cross-domain synthesis of the canonical barrier codes and therefore did not correspond one-to-one with the four original barrier domains. Both canonical barriers and higher-order themes were non-mutually exclusive where supported by the source.

Each primary publication was also classified according to technological generation as 5G precursor, B5G transition, direct 6G, or cross-generation. This classification was retained because the evidential character of identified barriers differs across generations. 5G studies can provide comparatively mature evidence concerning deployment, investment, adoption, revenues, operating costs, and organisational implementation, whereas much of the direct-6G literature remains prospective. Earlier-generation evidence was therefore interpreted as an empirical or operational antecedent to potential 6G realisation barriers rather than as direct evidence that identical commercial outcomes will occur under 6G.

Final RQ4 classifications were based on manual source-level verification of the underlying publications. Structured procedures were used to support organisation, prioritisation, and consistency checking, while final inclusion and coding decisions were determined through source-level assessment. Ambiguous

cases were re-examined in context, particularly where the relationship between a technical or prospective challenge and a business-model consequence was weak or indirect. Unsupported barrier assignments were removed or downgraded to contextual status where the required attribution could not be defended.

A conservative attribution principle was applied throughout. Where the evidence supported a general future-network challenge but did not establish a sufficiently clear business-model consequence, the case was retained as contextual or excluded rather than counted as positive barrier evidence. This approach prioritised specificity of attribution over maximising the number of identified barriers.

The final RQ4 synthesis combined structured qualitative barrier analysis with descriptive quantitative comparison. Frequencies and within-group percentages were used to examine the prevalence of barrier domains, canonical barriers, higher-order themes, and generation-specific patterns. Because publications could contain multiple barriers and contribute to more than one domain or higher-order theme, these dimensions were treated as multi-label and their percentages were not expected to sum to 100%. Generational comparisons were interpreted descriptively rather than inferentially, with particular caution applied to smaller B5G and direct-6G subsets.

3.6 Quality Assurance and Methodological Confidence

Given the heterogeneity of the reviewed literature, no single formal risk-of-bias or standardised study-quality scoring instrument was applied across the complete corpus. The review included conceptual, qualitative, empirical, simulation-based, techno-economic, and foresight-oriented studies whose evidential characteristics could not be meaningfully represented through a single common appraisal scale. Methodological confidence was therefore supported through a combination of predefined eligibility rules, RQ-specific analytical boundaries, source-level verification, conservative evidence attribution, and explicit consideration of evidence provenance and maturity.

A central quality assurance principle was that final analytical classifications had to be defensible from the underlying publication rather than from titles, abstracts, keyword occurrence, or isolated passages alone. Candidate passages and targeted within-document searches were used to locate potentially relevant evidence, but classification decisions were based on examination of the surrounding textual and methodological context. Where the available evidence was incomplete or ambiguous, additional sections of the same publication were examined before a final decision was made.

Particular attention was given to cases in which the analytical classification depended on a potentially ambiguous relationship between technical, business, or economic evidence. Higher risk and borderline cases were subjected to targeted re-examination, and wider consistency checks were subsequently performed across the relevant RQ-specific evidence bases. Where the available source material did not support a sufficiently clear attribution, the more conservative interpretation was retained. Depending on the analytical context, this could involve downgrading direct monetisation evidence to broader business/economic value, retaining a case as contextual rather than positive evidence, or excluding an unsupported relationship from the corresponding synthesis.

Structured and spreadsheet-based procedures were used during the review to support corpus organisation, evidence retrieval, prioritisation, consistency checking, and quality assurance. These procedures supported the analytical workflow but did not substitute for source-level assessment. Final screening, coding, attribution, and classification decisions were verified against the underlying publications, and keyword occurrence alone was not considered sufficient evidence for inclusion in an RQ-specific synthesis.

Quality assurance also involved maintaining explicit distinctions between different forms of evidence. In RQ2, evidence anchors were used as source-level retrieval and verification points, while the quantitative unit of analysis remained the paper-technical-enabler relationship. Direct monetisation was distinguished from broader business or economic value through explicit transaction-mechanism requirements. In RQ3, business/economic evaluation maturity was coded separately from supporting technical evidence so that simulation, prototypes, or testbeds were not automatically interpreted as validation of commercial viability. In RQ4, generic technical challenges were retained only where a sufficiently defensible connection to a business-model consequence could be established.

Evidence provenance and technological generation were also considered when interpreting findings. Empirical and techno-economic studies, conceptual and foresight research, industry-oriented cases, and secondary literature were not assumed to provide equivalent forms of evidence. Similarly, findings derived from 5G precursor studies were not interpreted as direct confirmation of future 6G outcomes. Earlier generation evidence was used to identify antecedent commercial structures, evaluation practices, value mechanisms, or implementation barriers, while B5G, cross-generational, and direct-6G evidence was retained separately to preserve differences in technological and commercial maturity.

The RQ-specific coding datasets were subjected to final consistency checking before descriptive synthesis. Once ambiguous classifications had been resolved and the relevant evidence layers had been verified, the analytical datasets were frozen to prevent subsequent interpretation from altering the underlying coding decisions. Descriptive frequencies and percentages were then calculated from these stabilised datasets according to the unit of analysis defined for each research question.

Taken together, these procedures were intended to provide a transparent and auditable analytical process appropriate to a heterogeneous and rapidly developing research field. Rather than relying on a single universal quality score, methodological confidence was supported by source-level traceability, explicit analytical boundaries, conservative attribution, separation of evidential dimensions, and final manual verification of substantive coding decisions.

3.7 Chapter Summary

This chapter described the methodological design of the Systematic Literature Review and the procedures used to construct and analyse the evidence base. The review combined preliminary scoping, a systematic multi-source search, deduplication and relevance screening, and the formation of a common corpus of 218 publications. The PRISMA 2020 framework informed the transparent reporting of the identification and screening process, while the study selection criteria established the common analytical boundary for the review.

Following formation of the common corpus, the publications were reassessed separately for each research question using RQ-specific analytical boundaries, units of analysis, coding frameworks, and evidential thresholds. RQ1 focused on business-model archetypes and their evolutionary positioning; RQ2 examined attributable relationships between technical enablers, value propositions, and mechanisms of value capture; RQ3 compared methodological approaches, evaluation strategies, and evidence maturity; and RQ4 analysed barriers and challenges affecting business-model realisation. Across these analyses, source-level verification, conservative attribution, explicit distinction between different forms of evidence, and final consistency checking were used to support methodological confidence. The following chapters present the results of these four analytical streams and examine what they collectively indicate about the emerging business-model landscape associated with the transition from 5G and B5G toward 6G.

4. RQ1 Business-Model Archetypes for 6G Networks

4.1 Composition of the RQ1 Evidence Base

Of the 218 publications reassessed for RQ1, 90 (41.3%) contained substantive business-model evidence within the defined network/service-ecosystem boundary and formed the primary analytical sample. Sixteen additional publications contained relevant but adjacent business-model evidence and were retained for boundary analysis, whereas 112 publications did not satisfy the RQ1 inclusion criteria.

The generation composition of the 90 primary publications demonstrates the importance of distinguishing precursor from direct-6G evidence. The largest component was the **5G precursor literature (n = 52)**, followed by **direct 6G (n = 17)**, **B5G transition (n = 12)**, and **cross-generation studies (n = 9)**. Thus, the evidence base captures both established commercial structures developed within 5G and the emerging literature examining their continuation or transformation toward 6G.

4.2 Business-Model Archetypes

The analysis identified ten recurrent business-model archetype families, which are summarised in Table 4.1.

Table 4.1: Business-model archetypes identified in the reviewed literature and their distribution by generation role

Archetype	n	%	5G	B5G	Direct 6G	Cross
Platform / ecosystem orchestrator	42	46.7%	22	6	11	3
Slice-as-a-Service / resource market	33	36.7%	23	4	3	3
Infrastructure / resource sharing / neutral host	29	32.2%	17	5	4	3
Network / capability-as-a-Service	28	31.1%	12	4	6	6
Vertical solution / integrated service provider	22	24.4%	20	0	2	0
Local/private network / micro-operator	18	20.0%	9	2	4	3
Data monetisation / data marketplace	8	8.9%	5	2	1	0
NTN / satellite / aerial connectivity model	7	7.8%	3	2	2	0
Sustainability-driven / green business model	5	5.6%	0	1	4	0
Decentralised / blockchain-enabled service marketplace	4	4.4%	0	0	3	1

Note: Archetypes were coded using a multi-label approach; therefore, category frequencies are not mutually exclusive and their sum exceeds the 90 primary RQ1 publications. Percentages are calculated using the 90 primary RQ1 publications as the denominator.

The most prevalent archetype was Platform / ecosystem orchestrator, identified in 42 publications (46.7%). This archetype describes configurations in which an operator, platform provider, or other coordinating actor facilitates interaction among multiple partners, service providers, resource providers, or customers within a network-enabled ecosystem. Platform-oriented and ecosystemic business-model configurations have been discussed explicitly in the context of 6G value creation and capture, as well as in prospective 6G service ecosystems [45], [46].

The second most frequent archetype was Slice-as-a-Service / resource market, appearing in 33 publications (36.7%). These models commercialise network slices or virtualised resource bundles through arrangements in which network or infrastructure providers allocate, sell, lease, price, or otherwise make configurable resources available to tenants and service providers. Such commercial configurations are reflected in studies examining business-model alternatives for future mobile operators and transactional or contractual mechanisms surrounding network slicing in 5G and beyond [47], [48].

Infrastructure / resource sharing / neutral host was identified in 29 publications (32.2%). This archetype encompasses models in which physical infrastructure, spectrum, virtual resources, or access capabilities are shared among multiple operators or service providers. Neutral-host arrangements and local or micro-operator configurations provide representative examples of how shared infrastructure and alternative ownership structures can support 5G-and-beyond network deployment [49], [50].

Closely following this was Network / capability-as-a-Service, appearing in 28 publications (31.1%). These models involve the commercial exposure of connectivity, network functions, capabilities, experimentation environments, or other programmable network resources as modular or on-demand services. Such service-oriented configurations are consistent with research examining future mobile-operator business models and the commercialisation of advanced network capabilities rather than connectivity alone [46], [47].

The Vertical solution / integrated service provider archetype appeared in 22 publications (24.4%). It represents configurations in which providers extend beyond connectivity provision to integrate network capabilities with sector-specific applications or services and therefore assume a broader solution-provider or system-integrator role. Research on next-generation public-safety mobile broadband illustrates how mobile operators may participate in broader service-delivery arrangements in which commercial viability, risk, and profitability depend on more than connectivity provision alone [51], [52].

Local/private network / micro-operator models were identified in 18 publications (20.0%), reflecting business arrangements in which dedicated local, campus, enterprise, or community networks are provided through specialised or locally oriented actors. The literature on local mobile-network regulation and micro-operator neutral-host configurations illustrates the emergence of alternative actor roles and locally bounded network-provision models beyond the conventional nationwide MNO structure [49], [50].

Data monetisation / data marketplace appeared in 8 publications (8.9%). This archetype captures configurations in which network- or service-generated data become resources for value creation, exchange, brokerage, or monetisation. Data-driven business-model innovation has been discussed explicitly in relation to 6G, while the 5GMETA framework provides a more concrete example of connecting data providers and consumers through a data-monetisation platform [53], [54].

NTN / satellite / aerial connectivity models were identified in 7 publications (7.8%). These configurations extend service provision and value creation across integrated terrestrial, satellite, and aerial connectivity environments. Representative studies include integrated satellite-cellular systems for

5G and beyond, techno-economic analysis of integrated satellite-5G connectivity, and prospective business configurations for connected aerial platforms in a 6G context [46], [55], [56].

Sustainability-driven / green business models appeared in 5 publications (5.6%). In this archetype, sustainability constitutes part of the underlying business-model and value-creation logic rather than merely a technical energy-efficiency objective. Ecosystemic 6G business scenarios have explicitly examined sustainability as both a constraint and driver of new business configurations, while subsequent work has considered green mobile-operator business models for 5G and beyond [57], [58].

Finally, Decentralised / blockchain-enabled service marketplaces appeared in 4 publications (4.4%). These models introduce decentralised governance, exchange, transaction, or settlement mechanisms into the provision and commercialisation of network resources and services. Blockchain-enabled ecosystemic business models have been proposed specifically in relation to 6G, while more recent work extends this logic toward trustworthy intent-based 6G service marketplaces using decentralised finance concepts [59], [60]. The frequency distribution of the identified archetypes is presented in Figure 4.1.

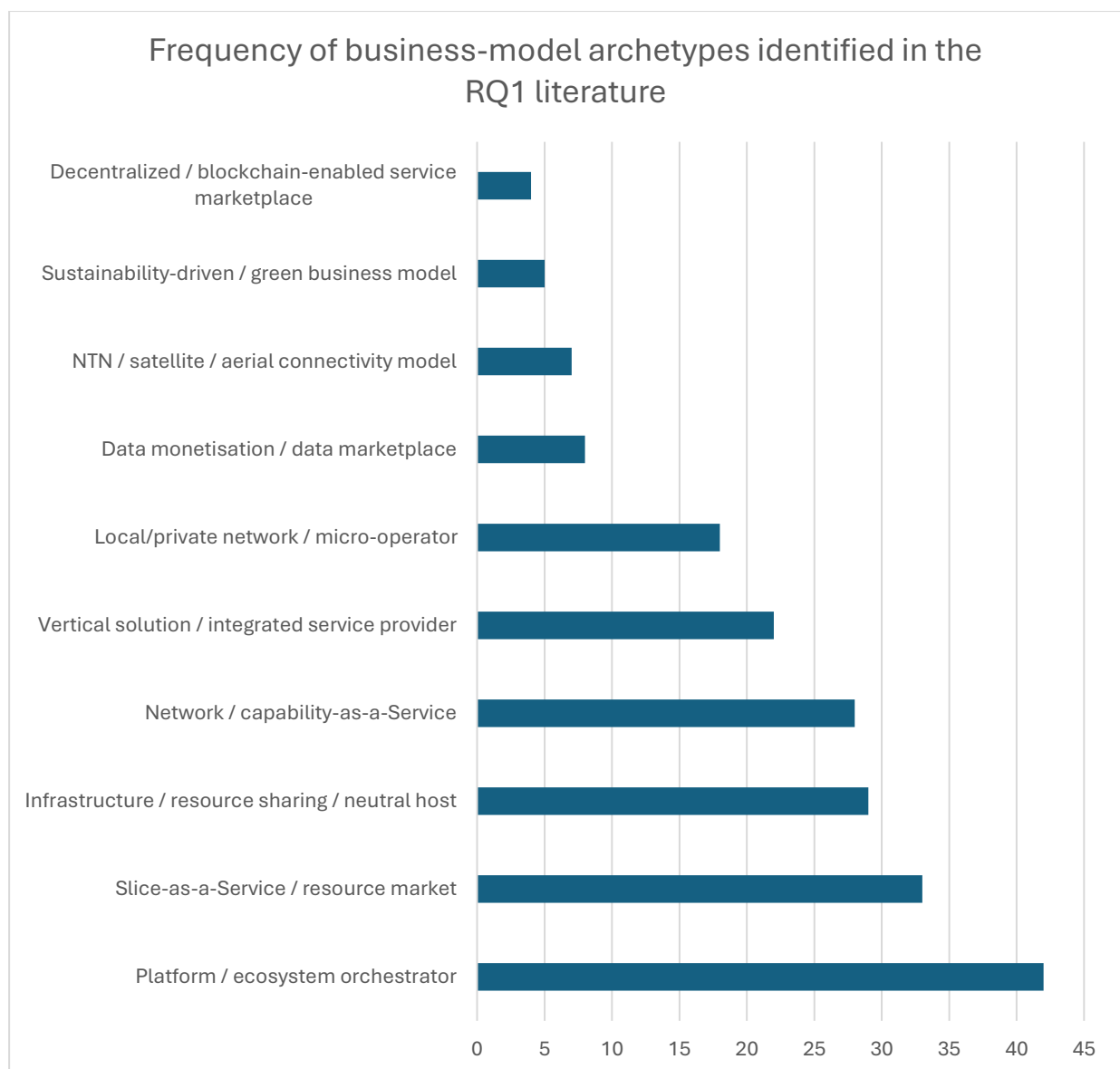


Figure 4.1: Frequency of business-model archetypes identified in the RQ1 literature

Note: Archetype coding was multi-label; therefore, frequencies exceed the 90 primary RQ1 publications when summed across categories.

Because archetype coding was multi-label, these frequencies represent the number of publications in which each configuration was substantively identified rather than mutually exclusive shares of the literature.

4.3 Generational Distribution of the Archetypes

The overall frequencies provide only part of the RQ1 result. Examination of the generation distribution reveals substantial variation in the extent to which individual archetypes are rooted in 5G or represented directly in the developing 6G literature. This generational distribution is presented in Figure 4.2.

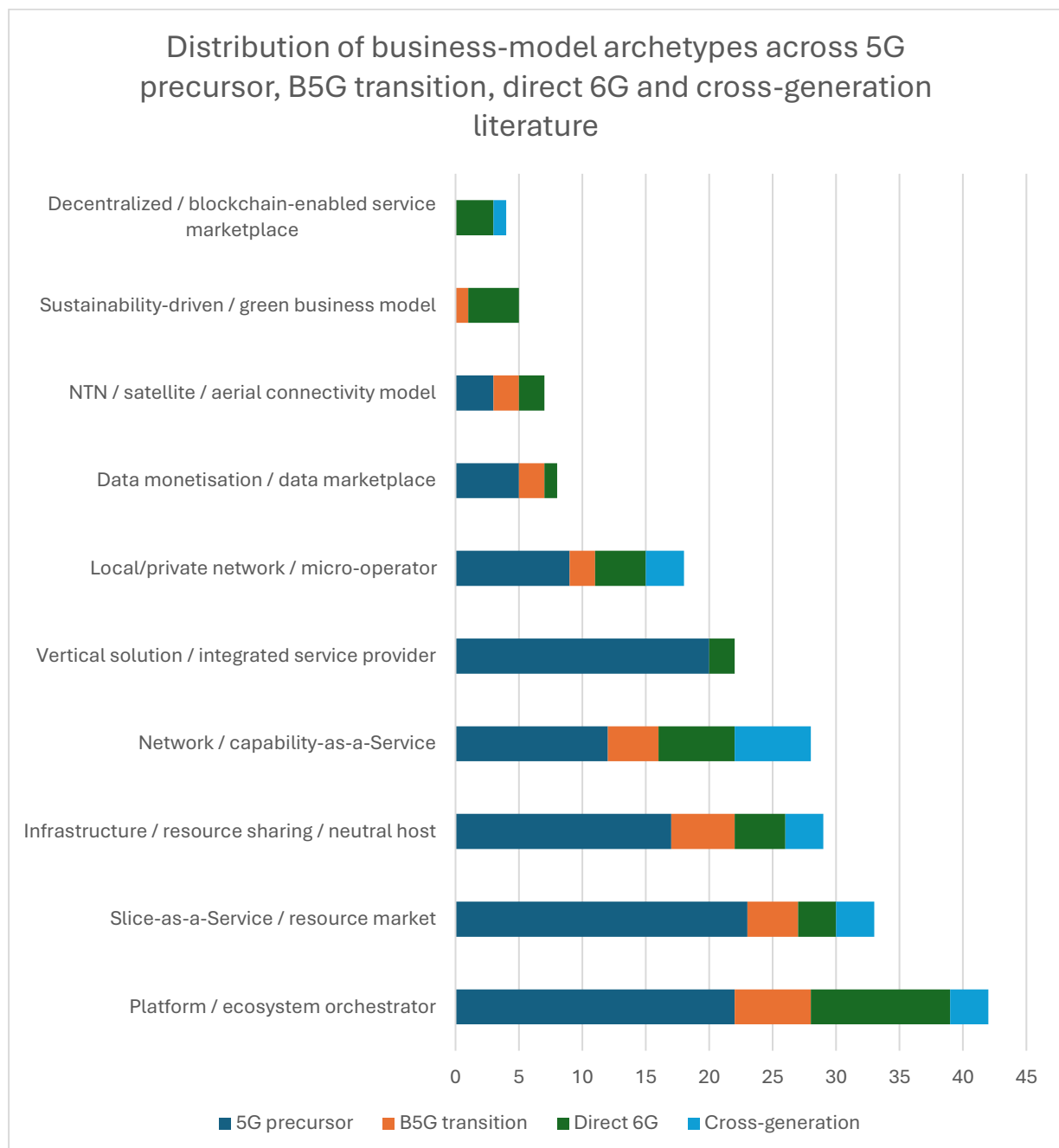


Figure 4.2: Distribution of business-model archetypes across 5G precursor, B5G transition, direct 6G, and cross-generation literature.

Note: Generation roles refer to the evidential positioning of each publication. Archetype coding was multi-label; consequently, the same publication may contribute to more than one archetype.

The Vertical solution / integrated service provider archetype was particularly concentrated in the 5G precursor literature. Of its 22 supporting publications, 20 were 5G precursor studies and only 2 were direct-6G studies. The archetype should therefore be interpreted primarily as an established 5G commercial configuration with potential relevance to future generations rather than as a distinctively 6G-originated model.

A similar pattern was observed for Slice-as-a-Service / resource market, for which 23 of the 33 publications were 5G precursors, compared with 4 B5G, 3 direct-6G, and 3 cross-generation publications. Infrastructure/resource sharing was also precursor-heavy, although its distribution was broader: 17 precursor, 5 B5G, 4 direct-6G, and 3 cross-generation publications.

Other archetypes showed substantially greater continuity between network generations. The Platform/ecosystem archetype comprised 22 precursor, 6 B5G, 11 direct-6G, and 3 cross-generation studies, providing both a substantial historical base and a relatively strong direct-6G presence.

Network/capability-as-a-Service exhibited an even more distributed generational profile. Its 28 supporting publications comprised 12 5G precursor, 4 B5G, 6 direct-6G, and 6 cross-generation studies. Local/private network models similarly combined 9 precursor, 2 B5G, 4 direct-6G, and 3 cross-generation publications, while NTN-related business models comprised 3 precursor, 2 B5G, and 2 direct-6G publications.

Two archetypes displayed a qualitatively different generation pattern. The Sustainability-driven / green business model category contained no 5G precursor publications; its five supporting studies consisted of one B5G and four direct-6G publications. Similarly, Decentralised / blockchain-enabled service marketplace contained three direct-6G and one cross-generation publication, with no 5G precursor study.

Although these two categories are comparatively small in absolute terms, their strong concentration in the forward-looking evidence base differentiates them from the more established commercial structures.

4.4 Evolutionary Positioning of the Business-Model Landscape

The generational patterns allowed the ten archetypes to be synthesised into three broader evolutionary positions, as summarised in Table 4.2. These positions constituted an interpretive synthesis of the distribution of the underlying archetypes rather than statistically inferred clusters or a second independent business-model taxonomy.

The 5G-established / inherited group comprised Slice-as-a-Service/resource markets, infrastructure/resource sharing/neutral hosts, vertical solution/integrated service providers, and data monetisation/data marketplaces. The cross-generational / evolving core comprised Platform/ecosystem orchestration, Network/capability-as-a-Service, local/private network models, and NTN/satellite/aerial connectivity models. Finally, Sustainability-driven / green business models and Decentralised / blockchain-enabled service marketplaces formed the 6G-emergent group.

Table 4.2: Paper-level evolutionary positioning of business-model archetypes across the 5G-to-6G literature

Evolutionary interpretation	Unique papers	5G precursor (n=52)	B5G (n=12)	Direct 6G (n=17)	Cross-generation (n=9)
5G-established / inherited	70	48 (92.3%)	8 (66.7%)	8 (47.1%)	6 (66.7%)
Cross-generational / evolving core	65	34 (65.4%)	9 (75.0%)	15 (88.2%)	7 (77.8%)
6G-emergent	9	0 (0.0%)	1 (8.3%)	7 (41.2%)	1 (11.1%)

Note: “Percentages within the generation columns represent the proportion of publications in that generation role containing at least one archetype from the corresponding evolutionary family (5G precursor n = 52; B5G transition n = 12; direct 6G n = 17; cross-generation n = 9). Evolutionary families are interpretive and non-mutually exclusive at publication level.”

Evolutionary positioning was examined at unique-publication level so that the same publication was not counted more than once within a given evolutionary family. Publications could nevertheless contribute to more than one evolutionary family where they contained archetypes belonging to different groups.

Across the 90 primary publications, 70 contained at least one established/inherited archetype, 65 contained at least one evolving-core archetype, and 9 contained at least one 6G-emergent archetype. Because publications could contain multiple archetypes, these groups overlap.

A pronounced generational difference was observed. Among the 52 5G precursor publications, 48 (92.3%) contained at least one established/inherited archetype. Thirty-four (65.4%) also contained an evolving-core archetype, whereas none contained an archetype classified as 6G-emergent.

Among B5G transition publications, 8 of 12 (66.7%) contained an established/inherited archetype and 9 (75.0%) contained an evolving-core configuration. Only one (8.3%) contained a 6G-emergent archetype.

The distribution changed substantially among the direct-6G literature. Of the 17 direct-6G publications, 15 (88.2%) contained at least one evolving-core archetype. Established/inherited configurations remained present in 8 publications (47.1%), demonstrating continued relevance of earlier commercial structures. However, 7 direct-6G publications (41.2%) also contained at least one 6G-emergent archetype.

The cross-generation group displayed a similar emphasis on evolutionary continuity: 7 of 9 publications (77.8%) contained evolving-core archetypes, while 6 (66.7%) contained established/inherited models and one contained a 6G-emergent archetype.

Overlap between the evolutionary groups was substantial. In particular, 46 of the 90 primary publications (51.1%) simultaneously contained at least one established/inherited and one evolving-core archetype. This provides additional evidence that the movement toward 6G is not simply characterised by replacement of earlier business models but by coexistence and recombination of commercial structures across generations.

4.5 Discussion of RQ1 Findings: Evolution of 6G Business-Model Archetypes

4.5.1 Continuity rather than wholesale replacement

The findings indicate that the developing 6G business-model landscape is characterised primarily by evolutionary continuity rather than wholesale replacement of 5G commercial structures.

Several of the most frequently observed archetypes have a substantial 5G precursor base. Slicing-based commercialisation, infrastructure and resource sharing, vertical solution provision, and data-based value capture were already prominent within 5G-oriented business-model discussions. Their presence in B5G and 6G studies consequently represents, at least in part, the continued development of previously established commercial mechanisms.

This result is important when interpreting claims regarding “new” 6G business models. High frequency within the complete literature should not be equated automatically with 6G specificity. The Vertical solution archetype, for example, is relatively frequent overall but overwhelmingly supported by 5G precursor evidence. By contrast, smaller categories such as sustainability-driven or decentralised models show a considerably stronger concentration in direct-6G publications.

The evidence therefore supports a distinction between prevalence and generational novelty.

4.5.2 Platformisation and capability-based service provision as an evolving core

Platform/ecosystem orchestration emerges as the most frequently identified archetype and also maintains a substantial presence in the direct-6G literature. This suggests that ecosystem coordination is not simply a legacy feature of 5G business-model thinking but remains important as future network environments become increasingly heterogeneous and multi-actor. Prior 6G-oriented research similarly emphasises ecosystemic value creation and capture, changing actor roles, and platform-based configurations as important components of future telecommunications business models [45], [46].

The strong position of Network / capability-as-a-Service reinforces this interpretation. Rather than limiting commercialisation to connectivity as a monolithic telecommunications product, the literature increasingly considers network capabilities, functions, resources, and service components as assets that can be exposed to external actors through modular or service-oriented arrangements. This orientation is also reflected in research examining business-model alternatives for 5G and future mobile network operators [47].

The combination of platform orchestration and capability-based service provision therefore points toward a broader transformation in telecommunications value creation. The reviewed literature increasingly frames value creation as depending not only on infrastructure ownership and operation, but also on ecosystem coordination, the exposure of programmable capabilities, and access to distributed network resources. Local/private networks and NTN-related configurations reinforce this trend by extending network provision beyond traditional nationwide operator structures and introducing more heterogeneous provider, ownership, and access arrangements [50], [55].

4.5.3 Slicing, sharing, and vertical integration as inherited commercial foundations

Slice-as-a-Service, infrastructure/resource sharing, and vertical solution provision remain substantial components of the overall taxonomy, but their generational distributions indicate that their commercial foundations are primarily rooted in the 5G literature. Existing studies already describe network slicing as a basis for differentiated commercial and service arrangements, while neutral-host and micro-operator

configurations demonstrate alternative approaches to infrastructure ownership, access, and sharing [47], [48], [49].

This should not be interpreted as evidence that these models are becoming irrelevant to 6G. Rather, they constitute commercial mechanisms through which network virtualisation, resource allocation, shared infrastructure, and specialised service provision may continue to be incorporated into future network ecosystems. Research on next-generation public-safety mobile broadband similarly illustrates how operator roles may expand toward broader integrated service arrangements whose commercial viability depends on risk allocation, service design, and profitability considerations [51], [52].

Their importance may therefore lie less in being uniquely new 6G business models and more in providing commercial building blocks that can be incorporated into increasingly platform-oriented, programmable, and heterogeneous future networks.

Data monetisation shows a related form of continuity. The archetype is not among the most frequent categories, and its evidence is concentrated primarily in earlier-generation studies, but it remains relevant to increasingly data-intensive network ecosystems. Its role in the transition towards 6G is therefore better interpreted as an inherited commercial logic that may be recombined with platform, marketplace, AI-enabled, and multi-actor service configurations rather than as a distinctly new 6G business model.

4.5.4 Emergence of sustainability and decentralised value-exchange logics

The two smallest archetypes present one of the most distinctive generational patterns.

Sustainability-driven business models differ from conventional treatments in which energy efficiency or environmental performance is considered only as a technical objective or source of cost reduction. Within the relevant literature, sustainability is also incorporated into ecosystem design, stakeholder relationships, and value-creation and value-capture considerations [57], [58].

Its concentration in B5G and direct-6G publications suggests that sustainability may be becoming more closely integrated with business-model design as the 6G literature develops.

Likewise, decentralised or blockchain-enabled service marketplaces introduce governance and exchange structures that differ from conventional centrally coordinated operator arrangements. Yrjölä (2020) explicitly considers how blockchain could support open ecosystemic 6G business models, while Jagadeesan et al. (2025) develop the marketplace logic further through trustworthy intent-based 6G services and decentralised finance mechanisms [59], [60].

These studies support the interpretation of decentralised marketplaces as a distinguishable, although still relatively small, business-model direction within the 6G-oriented literature. Their significance lies less in their current frequency than in the fact that decentralised governance, automated exchange, and new transaction mechanisms recur primarily within the forward-looking part of the evidence base.

4.5.5 Inheritance, evolution, and emergence

Taken together, the evidence can be interpreted through a three-part evolutionary process. Inherited archetypes provide commercial structures already developed within 5G, including slicing, infrastructure sharing, integrated vertical provision, and data monetisation.

The evolving core contains models whose relevance spans network generations and which appear particularly prominent in the forward-looking evidence base, including platform/ecosystem orchestration, capability-as-a-Service, local/private networks, and NTN-related models.

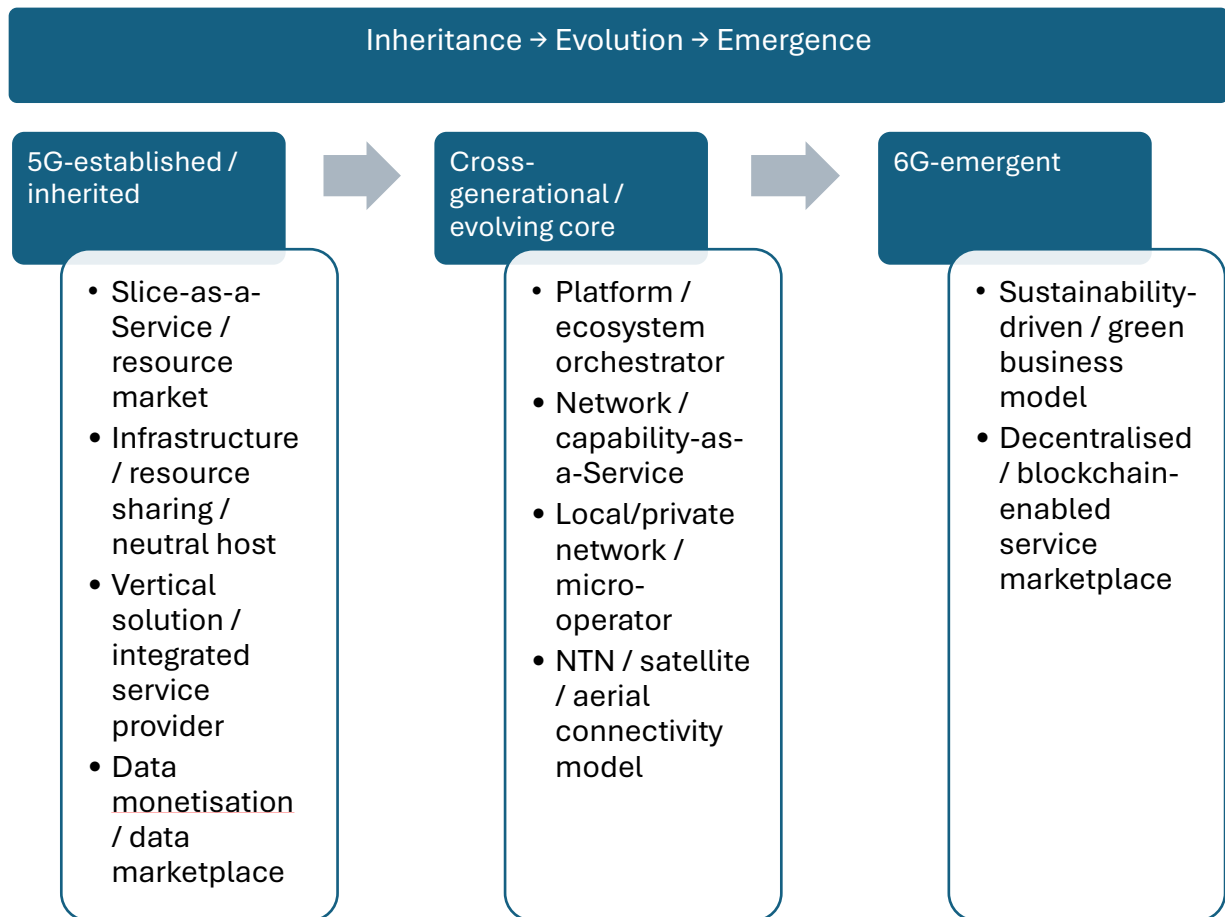


Figure 4.3: Evolutionary positioning of business-model archetypes across the 5G-to-6G transition.

Note: The three evolutionary positions constitute an interpretive synthesis layer over the ten final archetypes rather than a second mutually exclusive taxonomy.

Finally, the emergent layer introduces business-model logics whose evidence is concentrated much more strongly in the B5G and 6G literature, particularly sustainability-centred value creation and decentralised service marketplaces. This evolutionary positioning is illustrated in Figure 4.3.

The substantial overlap between these groups is itself informative. The finding that 46 publications combine established and evolving archetypes indicates that emerging network business models are frequently constructed through recombination and extension of existing commercial mechanisms, rather than through completely independent new structures. This also implies that novelty in 6G business models may reside less in the appearance of entirely new archetypes than in changes to how established mechanisms are combined, which actors control them, and how technical capabilities are exposed and exchanged across increasingly complex ecosystems. A slicing, sharing, or service-based mechanism may therefore be inherited from 5G while participating in a substantially different 6G value network.

The evidence therefore suggests that the transition toward 6G should be viewed as an evolutionary restructuring of the telecommunications business-model ecosystem, combining established commercial mechanisms with increasingly platform-oriented, capability-based, heterogeneous, sustainability-aware, and in some cases decentralised forms of value creation and exchange.

4.6 Direct answer to RQ1

RQ1 identified **ten recurrent business-model archetype families** within the reviewed scholarly literature: Platform/ecosystem orchestrator; Slice-as-a-Service/resource market; Infrastructure/resource sharing/neutral host; Network/capability-as-a-Service; Vertical solution/integrated service provider; Local/private network/micro-operator; Data monetisation/data marketplace; NTN/satellite/aerial connectivity model; Sustainability-driven/green business model; and Decentralised/blockchain-enabled service marketplace.

The results show that these archetypes do not have equivalent generational origins. A substantial proportion of the business-model landscape is rooted in 5G, particularly slicing-based commercialisation, infrastructure sharing, vertical solution provision, and data monetisation. Platform/ecosystem orchestration, capability-as-a-Service, local/private networking, and NTN-related models exhibit stronger continuity across generations and form an evolving commercial core within the transition toward 6G.

At the same time, sustainability-driven business models and decentralised service-marketplace configurations display a comparatively strong concentration in the direct-6G literature, suggesting the emergence of additional value-creation and governance logics.

Overall, the literature therefore portrays the transition toward 6G not as the replacement of established 5G business models by an entirely new set of configurations, but as a combination of inherited commercial foundations, cross-generational adaptation, and a smaller set of comparatively emergent 6G-oriented business-model logics.

4.7 RQ1-specific limitations

The interpretation of RQ1 should account for the developmental stage of the underlying literature. Only 17 of the 90 primary publications were classified as direct-6G studies, whereas 52 represented 5G precursor evidence. The identification of future 6G business-model archetypes therefore necessarily combines direct 6G evidence with analysis of commercial structures established in earlier network generations.

Furthermore, inclusion did not require empirical demonstration or commercial deployment. Conceptual and prospective models were deliberately retained when they substantively articulated business-model mechanisms, reflecting the exploratory state of the 6G literature. Consequently, the identified archetypes should be interpreted as business-model configurations proposed, discussed, or studied in the literature, rather than as evidence that these models have already achieved market adoption.

The taxonomy is also multi-label. Individual publications may support several archetypes, meaning that category frequencies should not be interpreted as mutually exclusive market shares. Similarly, the established/evolving/emergent classification represents an interpretive synthesis of the generational distribution of the ten archetypes rather than a statistically derived classification.

Finally, the smaller number of studies supporting sustainability-driven and decentralised business models warrants caution. Their concentration in the 6G-oriented literature constitutes a meaningful emerging pattern, but further research will be required to determine whether these configurations become persistent elements of the future telecommunications business-model landscape.

5. RQ2: Technical Enablers, Value Propositions and Value Capture

5.1 Evidence Base and Analytical Scope

The analysis of RQ2 examined how technical enablers associated with 5G evolution, beyond-5G (B5G), and emerging 6G architectures were linked to value propositions, business or economic value, and explicit mechanisms of value capture. From the original corpus of 218 papers, the final core synthesis retained 112 positive paper-technical-enabler relationships that satisfied the attribution requirements established in the methodology. A further 24 contextual or boundary relationships were retained for audit purposes but were not included in the core positive synthesis because they did not provide sufficiently defensible enabler-level attribution.

Following the coding framework described in the methodology, the retained evidence was differentiated according to the specificity of the value-capture relationship. Thirty-five relationships contained direct monetisation evidence, meaning that the technical enabler could be linked to an explicit monetisation or value-capture mechanism, such as leasing, usage-based charging, subscription, SLA-linked charging, resource trading, licensing, or implementation fees. The remaining 77 relationships contained identifiable business or economic value but no sufficiently specific monetisation mechanism attributable to the same technical enabler.

Consequently, direct monetisation accounted for 35 of the 112 positive paper/technical-enabler relationships (31.3%), whereas 77 relationships (68.8%) reflected business or economic value without an explicit transaction mechanism. This distinction was important because statements concerning cost reduction, operational efficiency, differentiation, flexibility, market opportunities, or potential revenue generation were not considered sufficient evidence of direct monetisation unless the source also specified a sufficiently explicit monetisation or value-capture mechanism attributable to the same technical enabler.

The quantitative findings reported in the following sections should therefore be interpreted as the distribution of evidence within the reviewed literature, rather than as measures of market size, realised revenue, commercial success, or the intrinsic importance of individual technologies. The analysis represents a structured qualitative synthesis complemented by descriptive quantitative relationship counts, rather than a statistical meta-analysis.

5.2 Technical Enablers and Monetisation Evidence

The distribution of monetisation and business/economic value evidence across the identified technical enablers is presented in Figure 5.1. The results reveal substantial variation both in the overall volume of evidence associated with individual enablers and in the extent to which their technical capabilities were translated into explicit mechanisms of value capture.

Network Slicing exhibited the strongest concentration of direct monetisation evidence within the reviewed corpus. It accounted for 37 paper-technical-enabler relationships, of which 21 contained direct monetisation mechanisms and 16 described business or economic value without an explicit transaction mechanism. Direct monetisation therefore represented approximately 56.8% of the slicing-related evidence. Moreover the 21 Network Slicing relationships accounted for 60% of all 35 direct-monetisation relationships identified in the final synthesis. This indicates that Network Slicing was the most extensively evidenced technical enabler in relation to explicit value capture within the reviewed

literature. However, this finding should not be interpreted as evidence that slicing is inherently the most profitable or commercially important network technology.

This concentration is consistent with the technical characteristics of Network Slicing, through which logically isolated and configurable network resources can be tailored to heterogeneous customer and application requirements. Such differentiation enables network characteristics to be translated into more granular service offerings and, where an explicit charging mechanism is specified, into differentiated forms of value capture [61], [62], [63].

The underlying literature illustrates several ways in which slicing capabilities can be transformed into monetisable services. Cloud-network slicing has been conceptualised through a Slice-as-a-Service (SlaaS) model in which a tenant requests an end-to-end slice from a provider and gains access to, and management of, the associated physical or virtual resources. The same architecture allows tenants to sublet slice resources and services to other tenants, while elasticity enables allocated resources to expand or contract according to service requirements. This provides a traceable pathway from technical resource isolation and elasticity to service productisation and leasing- or subletting-based value capture [64].

A more explicitly market-oriented configuration models Network Slicing as a competitive resource-trading environment involving infrastructure providers, mobile virtual network operators (MVNOs), and end users. Within this model, competing MVNOs determine differentiated unit prices, users adjust their purchasing volumes according to the offered prices, and infrastructure resources are leased to MVNOs before being allocated or subleased to users. Network Slicing can therefore support not only differentiated service provisioning but also an explicit marketplace for dynamically priced network resources [65].

Other technical enablers also displayed direct monetisation evidence, although at considerably lower frequencies MEC / Edge Computing accounted for 16 paper-technical-enabler relationships, including 3 with explicit monetisation mechanisms; NTN accounted for 11 relationships, including 3 with direct monetisation evidence; and NFV accounted for 10 relationships, also including 3 with direct monetisation evidence. Explicit value-capture mechanisms were additionally identified for Heterogeneous Networks, Network Softwarisation, Small Cells / Ultra-Densification, Open RAN, and Intent-Based Networking, although each was represented by substantially fewer direct-monetisation relationships than Network Slicing. For several infrastructure-oriented enablers, the dominant pathway was instead indirect: technical improvements in capacity, spectral efficiency, programmability, flexibility, or deployment economics contributed to business value without necessarily producing a separately identifiable charging mechanism [61], [66], [67]. Smaller subsets of MEC/Edge Computing, NFV, NTN and other enablers nevertheless also exhibited explicit direct-monetisation mechanisms, as reflected in the final evidence distribution.

The distinction between business value and direct monetisation is particularly visible in the MEC/Edge evidence. In on-demand vehicular fog computing, mobile fog nodes can be dynamically routed towards locations where computing demand emerges, linking flexible edge capacity to measurable service consumption. The associated techno-economic formulation evaluates both service performance and revenue and models revenue at the level of individual computing tasks. Each task carries a price, while realised revenue is reduced when latency exceeds predefined service-level thresholds. The proposed multi-agent reinforcement-learning approach was reported to achieve 8.3% higher modelled revenue than a decentralised-learning baseline. This provides a clear example in which a technical capability dynamic, on-demand edge capacity is connected to a measurable service unit and an explicit usage-based revenue mechanism [68].

By contrast, other enablers exhibit identifiable economic value without an equally explicit customer transaction. Techno-economic analysis of MIMO and Distributed Antenna System deployments, for example, evaluates capital expenditure (CAPEX), operational expenditure (OPEX), and total cost of ownership (TCO) and demonstrates how technical deployment choices affect infrastructure economics and investment considerations. However, no independent mechanism is specified through which Massive MIMO itself is priced, leased, licensed, or otherwise commercialised as a distinct customer-facing resource. Such evidence was therefore interpreted as business or economic value rather than direct monetisation [69].

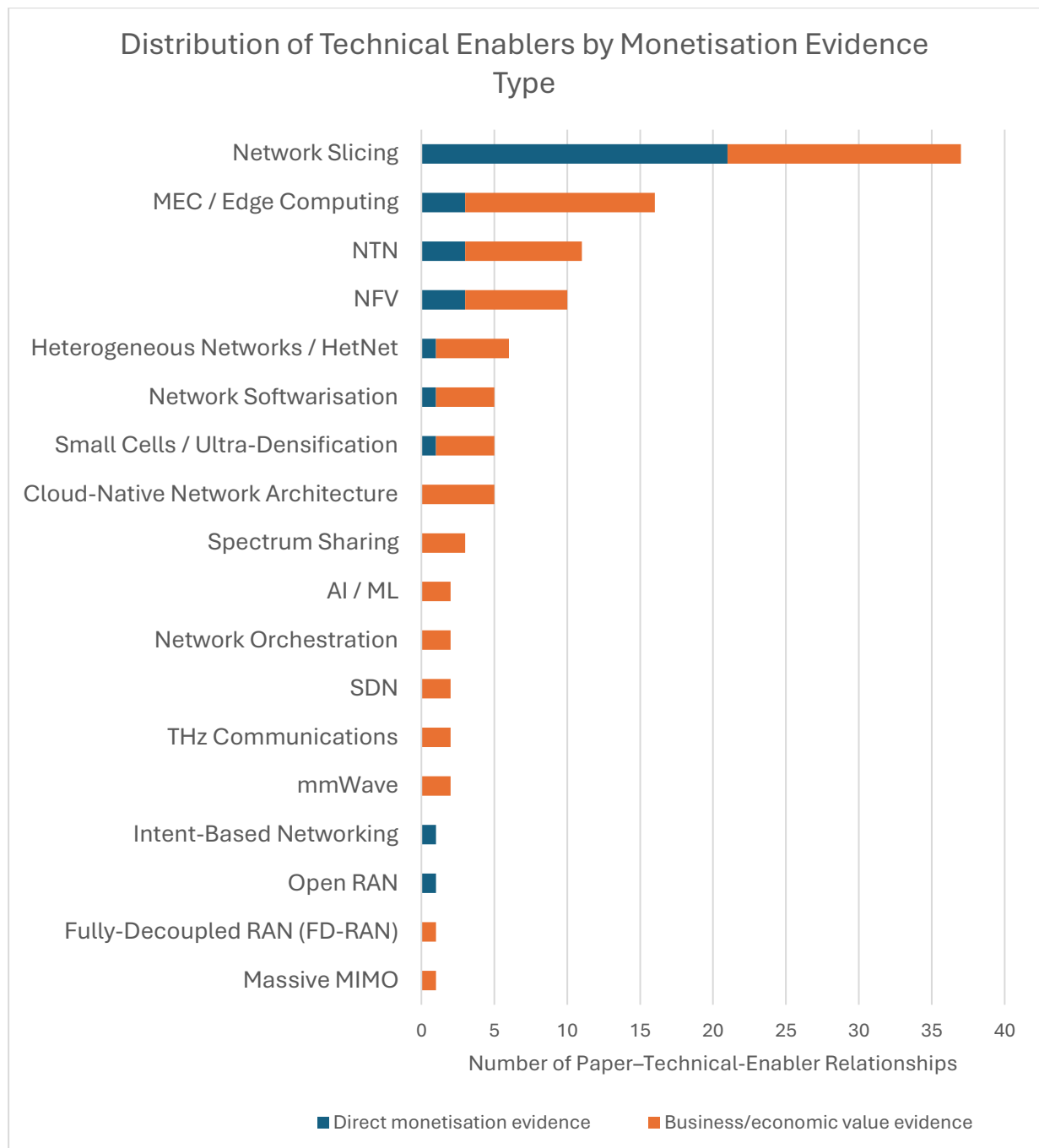


Figure 5.1: Distribution of technical enablers by business-evidence type.

Note: Distribution of technical enablers according to the type of business evidence identified in the reviewed corpus. Direct monetisation evidence corresponds to cases with an explicit enabler-attributable

transaction mechanism, whereas business/economic value evidence includes cases without an explicit monetisation mechanism.

It is also important to distinguish explicit monetisation evidence from realised commercial revenue. The reviewed evidence includes monetisation mechanisms that are proposed, simulated, or evaluated through techno-economic models rather than observed in mature commercial deployments. Competitive resource pricing in sliced networks, task-level fog-computing revenue, and intent-based 6G service marketplaces provide examples of such modelled or proposed mechanisms [60], [65], [68]. Accordingly, the presence of a direct monetisation mechanism should be interpreted as evidence that a technically attributable pathway to value capture has been articulated, rather than as evidence that the corresponding revenue stream has already been commercially realised.

Taken together, the distribution shown in Figure 5.1 indicates that the reviewed literature contains substantially more evidence of value creation associated with technical enablers than of explicit mechanisms for capturing that value through transactions. Network Slicing represents the clearest exception, as its technical properties-including resource isolation, programmability, elasticity, and service differentiation-are repeatedly associated with service productisation, leasing, unit-based pricing, SLA-linked charging, and resource trading. For most other enablers, the literature more commonly identifies cost reduction, performance improvement, infrastructure flexibility, coverage extension, automation, or ecosystem participation without specifying an equally explicit pricing or transaction mechanism.

5.3 Evolution from 5G Precursors towards 6G

The generation-based analysis revealed differences in how business value and monetisation are articulated across the transition from 5G to emerging 6G research. As shown in Table 5.1, the 112 positive paper-technical-enabler relationships comprised 67 5G-precursor, 2 B5G-transition, 27 6G-oriented, and 16 cross-generation cases.

Table 5.1: Distribution of RQ2 evidence by technological generation and monetisation type.

Technological generation	Direct monetisation evidence	Business/economic value evidence	Total relationships	Direct monetisation share
5G Precursor	24	43	67	35.8%
B5G Transition	1	1	2	50.0%
6G-Oriented	5	22	27	18.5%
Cross-Generation	5	11	16	31.3%
Total	35	77	112	31.3%

Note: Direct monetisation share represents the proportion of paper-technical-enabler relationships containing an explicit enabler-attributable monetisation mechanism within each technological-generation category.

Direct monetisation share represents the proportion of paper-technical-enabler relationships containing an explicit enabler-attributable monetisation mechanism within each generation category. The B5G Transition category contains only two paper-technical-enabler relationships and is therefore not interpreted comparatively. Across the overall positive RQ2 evidence base, 35 of the 112 positive paper/technical-enabler relationships (31.3%) contained an explicit monetisation mechanism that could be directly attributed to the corresponding technical enabler. This proportion varied across technological generations, accounting for 35.8% of the 5G-precursor evidence and 18.5% of the 6G-oriented evidence. Given the very small B5G-transition subset ($n = 2$), its apparent 50% share was not interpreted comparatively.

Within the 5G-precursor evidence, explicit monetisation mechanisms were comparatively more prominent and were frequently associated with technologies whose service and resource abstractions had already developed sufficiently to support identifiable transaction models. Network Slicing provides the clearest illustration of this pattern. Cloud-network slicing has, for example, been conceptualised through a Slice-as-a-Service (SlaaS) model in which tenants request elastic end-to-end slices, access and manage the associated physical or virtual resources, and may subsequently sublet resources and services to other tenants. The same architecture incorporates dynamic elasticity, allowing allocated resources to expand or contract according to service requirements [64].

Network Slicing has also been modelled as a competitive resource-trading environment involving infrastructure providers, MVNOs, and end users. In such a configuration, infrastructure capacity is leased to MVNOs, which subsequently offer or sublease resources to users while dynamically adjusting differentiated unit prices according to network conditions and purchasing behaviour. This provides a comparatively explicit pathway from network-resource abstraction to resource purchasing, differentiated pricing, and revenue generation [65].

These cases illustrate how parts of the 5G-precursor literature have progressed beyond identifying general business opportunities toward specifying what resource or service is exchanged, which actors participate in the transaction, and through which mechanism value can be captured. Leasing, subletting, differentiated unit pricing, SLA-linked charging, and other explicit transaction mechanisms are therefore more frequently articulated in the 5G-precursor evidence than in the emerging 6G-oriented subset.

The 6G-oriented evidence displayed a different overall emphasis. Of the 27 6G-oriented relationships, 22 were associated with business or economic value without an explicit monetisation mechanism. Much of this literature focuses on establishing the technical and techno-economic feasibility of emerging architectures, identifying future service capabilities, or determining the economic conditions under which new technologies may become viable.

This pattern is visible in Fully-Decoupled RAN, where independent uplink and downlink base-station deployment is proposed as a means of responding more efficiently to differentiated service demand. The associated techno-economic model focuses primarily on deployment-cost minimisation and infrastructure-investment efficiency, with simulation results indicating cost advantages under differentiated demand conditions. The resulting economic pathway is explicit, but the value arises primarily from improved deployment economics rather than from a separate customer-facing transaction mechanism [70].

A similar orientation appears in emerging 6G transport technologies. Hybrid FSO–THz access networks have been evaluated through cost–availability analysis to determine the conditions under which wireless links could provide a cost-effective alternative or complement to fibre infrastructure. The analysis quantifies CapEx trade-offs and identifies technology-cost thresholds relevant to future deployment, but does not specify an independent transaction mechanism through which the THz capability itself would be commercialised [71].

The NTN evidence similarly emphasises future service feasibility and deployment economics. Integrated LEO satellite, HAPS, and UAV architectures are associated with global and remote-area coverage, network augmentation, resilience, and on-demand capacity. Their economic assessment primarily concerns differences in total cost of ownership and the suitability of alternative non-terrestrial platforms for particular service scenarios. This represents a clear technical-to-economic-value relationship, but not necessarily direct monetisation of the underlying NTN technology itself [72].

The predominance of business/economic-value evidence in the 6G-oriented subset does not, however, indicate an absence of explicit future monetisation mechanisms. A smaller number of studies already describe more concrete forms of prospective 6G value capture. In softwarised 6G architectures, for example, telecommunications service providers may make available network devices and resources to service providers, while tailored service-function chains are assembled from softwarised resource and function blocks. Such configurations illustrate how network softwarisation can support service-oriented resource relationships and payments between multiple ecosystem actors [73].

An even more explicit transaction structure appears in proposed intent-based 6G service marketplaces. Composite services are envisioned as being bought and sold across multi-stakeholder environments, with service requests incorporating both technical requirements and economic constraints. A representative holographic healthcare scenario combines a maximum acceptable service price with an SLA-linked refund mechanism, while smart-contract functionality is used to support payments and financial penalties. This demonstrates that explicit value-capture mechanisms are already being conceptualised in 6G research, although such arrangements remain proposed marketplace architectures rather than evidence of mature commercial deployment [60].

Taken together, the generation-based distribution indicates a difference in the specificity and articulation of monetisation evidence across generations rather than establishing a difference in underlying monetisation potential. Direct monetisation mechanisms were identified in approximately 35.8% of the 5G-precursor evidence, compared with approximately 18.5% of the 6G-oriented evidence. The 5G literature more frequently specifies identifiable transactions such as leasing, resource trading, usage-based pricing, or service-level charging, whereas 6G-oriented research more commonly examines prospective value propositions, future ecosystem configurations, deployment economics, and techno-economic feasibility.

This pattern is consistent with the different stages of technological development represented by the reviewed literature. Evidence from 5G and B5G can therefore be used to identify value-creation and monetisation mechanisms that have already begun to emerge around technologies expected to remain relevant in future networks, while 6G-oriented studies provide indications of how these mechanisms may evolve as network architectures become increasingly softwarised, distributed, intelligent, and multi-stakeholder. Importantly, a monetisation mechanism identified in the 5G literature was not assumed to transfer automatically to 6G. The cross-generation comparison was instead used to distinguish mechanisms that are already comparatively well-articulated from those that remain prospective within emerging 6G business configurations.

Emerging 6G-oriented business configurations further extend this logic towards more distributed and ecosystem-based forms of value creation. Cloud-native architectures, open interfaces, virtualisation, specialised slicing, and AI/ML-enabled orchestration are increasingly discussed as mechanisms for abstracting and coordinating network capabilities across multiple service layers, supporting service-oriented and multi-actor configurations [20]. In this context, value creation may become less dependent on a linear operator-to-customer relationship and more dependent on the interaction of infrastructure providers, platforms, service providers, vertical industries, and complementary technology actors. These configurations remain predominantly forward-looking and therefore require further empirical validation as 6G technologies and markets mature [20], [74], [28].

5.4 Value Propositions Enabled by Technical Enablers

The analysis identified nine recurring primary value-proposition categories through which technical enablers were connected to business and economic value. Their distribution across the 112 positive paper-technical-enabler relationships is presented in Figure 5.2. The results indicate that value creation was concentrated in a relatively small number of recurring propositions, although the nature of the resulting business value varied substantially across technologies.

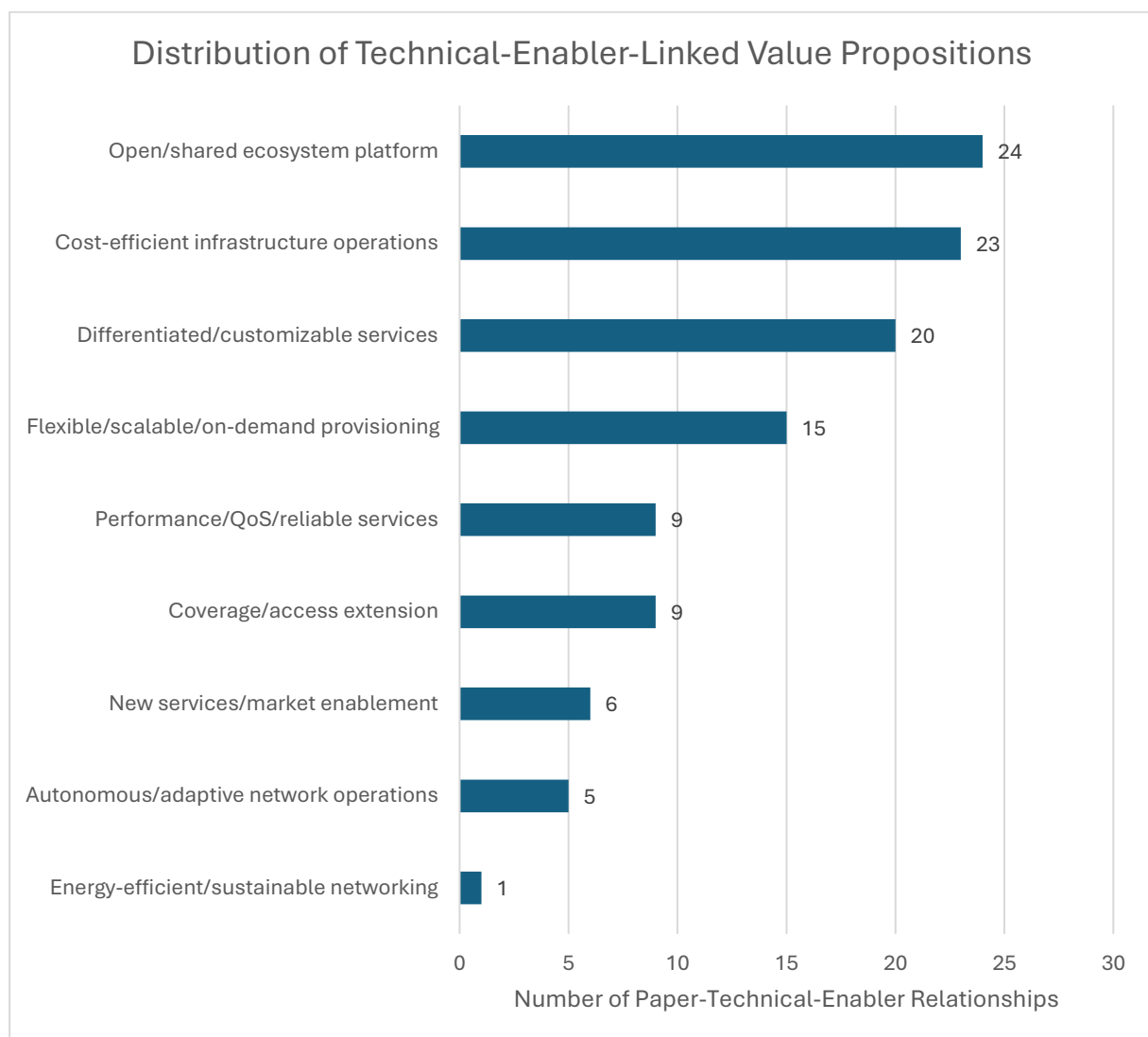


Figure 5.2: Distribution of technical-enabler-linked value propositions.

Note: Distribution of the final primary value propositions identified across the 112 positive paper-technical-enabler relationships.

The most frequently identified value proposition was Open/Shared Ecosystem Platform, accounting for 24 of the 112 relationships. This category captured cases in which technical capabilities enabled shared infrastructures, multi-actor service environments, platform-based interactions, or more open relationships between network operators, service providers, vertical industries, and other ecosystem participants. Such configurations are particularly visible in service-oriented and virtualised environments, where network functions and infrastructure capabilities can be combined across multiple actors rather than being confined to vertically integrated operator structures. Commercial 5G experimentation, for example, has been conceptualised through value networks involving infrastructure operators, solution providers, network operators, virtualisation providers, and vertical customers, with service and monetary flows occurring across the resulting ecosystem [75], [74].

Cost-Efficient Infrastructure and Operations represented the second most frequent value proposition, with 23 relationships. Here, the principal value of the technical enabler arose from its ability to reduce infrastructure expenditure, operating costs, resource requirements, or deployment complexity. This category therefore reflects an important form of business value that does not necessarily depend on selling the technical capability as a separate product. Techno-economic analyses of network technologies illustrate this distinction by linking deployment choices to CAPEX, OPEX, and total cost of ownership without necessarily defining a corresponding customer-facing transaction mechanism. This pattern is visible, for example, in the economic assessment of MIMO-based deployment alternatives [69].

The third-largest category was Differentiated/Customizable Services, accounting for 20 relationships. In these cases, the principal contribution of the technical enabler was the ability to tailor network characteristics or service configurations to different customers, vertical industries, or application requirements. Such differentiation may involve different levels of capacity, reliability, latency, security, isolation, or other service attributes. Network Slicing is particularly relevant to this value proposition because programmable and logically isolated network resources allow services to be configured according to heterogeneous requirements. More broadly, 5G industrial configurations demonstrate how common infrastructure can be adapted to differentiated business needs and application-specific requirements.

A further 15 relationships were classified as Flexible/Scalable/On-Demand Provisioning. This value proposition reflects the ability to dynamically allocate, expand, reduce, or reconfigure technical resources according to changing service requirements. Cloud-network slicing provides a clear illustration: slice resources can be dynamically increased or decreased through vertical and horizontal elasticity, while tenants can manage the resources associated with their requested slices. The resulting value lies primarily in the ability to match infrastructure provision more closely to service demand rather than maintaining a fixed resource configuration [64].

Taken together, these four leading categories-Open/Shared Ecosystem Platform, Cost-Efficient Infrastructure and Operations, Differentiated/Customizable Services, and Flexible/Scalable/On-Demand Provisioning-accounted for 82 of the 112 positive paper/technical-enabler relationships, or approximately 73.2% of the final evidence base. The concentration suggests that much of the identified business value originates from four broad transformations: opening network resources to wider ecosystems, improving infrastructure economics, enabling more differentiated service configurations, and increasing the flexibility with which resources can be provisioned.

The remaining value propositions were less frequent but represented distinct forms of technical-to-business value. Performance/QoS/Reliable Services and Coverage/Access Extension each accounted for 9 relationships. The former captured cases in which the principal value arose from improved reliability, latency, service quality, or other performance characteristics, whereas the latter represented technologies whose immediate contribution was to extend connectivity or service availability beyond the effective reach of existing terrestrial infrastructure. Satellite and other non-terrestrial architectures are particularly representative of the latter pathway, since their economic relevance is closely connected to extending broadband access and backhaul into remote or otherwise costly-to-serve areas [76].

New Services/Market Enablement accounted for 6 relationships, representing cases in which the technical capability primarily enabled previously unavailable applications, service categories, customer segments, or market configurations. Autonomous/Adaptive Network Operations, identified in 5 relationships, captured the value arising from increasingly automated monitoring, optimisation, intent processing, and dynamic network reconfiguration. Emerging AI-enabled and intent-based networking approaches illustrate this pathway by reducing the need for manual intervention while improving the network's ability to adapt to changes in demand, service requirements, and operating conditions. Such capabilities have also been associated with reductions in OPEX and energy consumption alongside improvements in performance and flexibility [77].

Finally, Energy-Efficient/Sustainable Networking appeared as the primary value proposition in only one relationship. This low frequency should not be interpreted as indicating that sustainability is unimportant to future network development. Rather, under the coding framework applied here, energy efficiency was assigned as the primary value proposition only when it constituted the most immediate enabler-linked source of value. In other cases, energy savings could appear as a secondary business impact associated with broader propositions such as cost efficiency or autonomous network operation.

The distribution of value propositions also demonstrates why value creation should not be equated with direct monetisation. The two most frequent value propositions did not exhibit the same monetisation profile. Of the 24 Open/Shared Ecosystem Platform relationships, 10 contained direct monetisation evidence and 14 reflected wider business/economic value. By contrast, only 2 of the 23 Cost-Efficient Infrastructure and Operations relationships contained an explicit value-capture mechanism, while 21 represented economic value without a specified transaction mechanism. Differentiated/Customizable Services and Flexible/Scalable/On-Demand Provisioning showed stronger connections to explicit value capture, with 11 of 20 and 9 of 15 relationships respectively containing direct monetisation evidence.

This distinction suggests that technical enablers contribute to business-model development through different pathways. Some primarily improve the economics of network provision, for example through cost reduction or resource efficiency, while others create capabilities that can more readily be transformed into differentiated, configurable, or transaction-ready services. The value-proposition layer therefore provides the analytical bridge between the technical capabilities identified in the literature and the monetisation mechanisms examined in the following section.

5.5 Direct Monetisation Mechanisms

The analysis of the 35 direct-monetisation relationships identified eight monetisation mechanisms that appeared as primary forms of value capture. Their distribution is presented in Figure 5.3. The results indicate that direct monetisation was concentrated primarily in mechanisms that transform technical resources or service capabilities into leaseable, measurable, tradable, or differentiated commercial offerings.

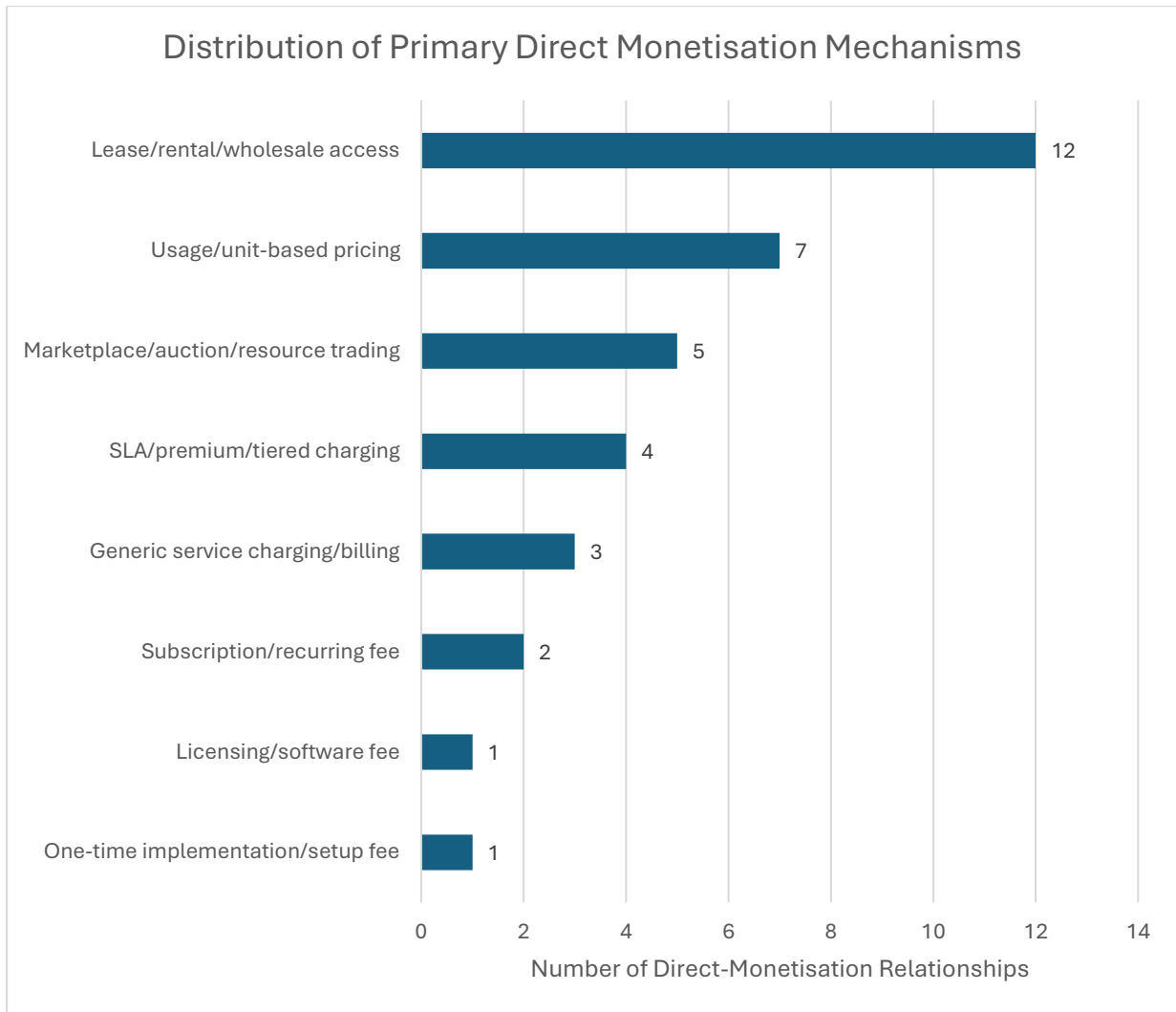


Figure 5.3: Distribution of primary direct monetisation mechanisms in the RQ2 evidence base.

Note: Distribution of the final primary monetisation mechanisms across the 35 direct-monetisation paper-technical-enabler relationships.

The most frequent primary mechanism was Lease/Rental/Wholesale Access, which accounted for 12 of the 35 direct-monetisation relationships, or approximately 34.3%. This category captured cases in which network resources, infrastructure, slices, spectrum, or other technically enabled capabilities were made available to another actor in exchange for access-related payment. Network slicing provides a representative example, as Slice-as-a-Service configurations can allow tenants to request and manage dedicated resources and subsequently sublet those resources or services to other tenants [64]. Similar value-capture logic appears in heterogeneous-network configurations in which a small-cell operator leases spectrum from a macro-cell operator, thereby linking multi-tier network coexistence to an explicit inter-operator transaction [78].

The second most frequent mechanism was Usage/Unit-Based Pricing, identified in 7 relationships, or 20.0% of the direct-monetisation evidence. This mechanism links payment to a measurable unit of resource or service consumption rather than to general access. Examples include computing tasks, traffic volume, users, sessions, or other quantifiable service units. In on-demand vehicular fog computing, for instance, computing services are evaluated through task-level pricing, with provider revenue linked to individual tasks and adjusted according to latency-related service conditions [68]. The same study

models revenue directly within the techno-economic optimisation and evaluates the resulting performance through simulation. Unit-based value capture also appears in satellite-network analysis, where service traffic is assessed using a price-per-GB basis within a model of prospective satellite-enabled connectivity [76].

Marketplace/Auction/Resource Trading represented the third largest primary category, accounting for 5 relationships, or approximately 14.3%. In these cases, monetisation depended not simply on providing access to a resource but on organising technical resources or composite services within a market in which buyers and sellers interact through dynamic pricing, trading, negotiation, or auction-like mechanisms. Sliced mobile networks provide a clear example: MVNOs can compete as resource sellers by setting differentiated unit prices, while users adjust their purchasing volumes according to the prices offered. The resulting model explicitly connects resource abstraction and slicing to a multi-sided trading marketplace [65].

A prospective extension of this market-based logic is visible in emerging intent-based 6G architectures. Composite services can be formulated as high-level intents containing technical requirements, price constraints, and SLA conditions, with service providers and intermediaries competing to fulfil these requests. Proposed marketplace architectures additionally incorporate smart-contract payments and financial penalties or refunds where agreed service conditions are violated [60].

SLA/Premium/Tiered Charging was the primary mechanism in 4 relationships, representing approximately 11.4% of the direct-monetisation evidence. This category captured cases in which payment was explicitly linked to differentiated service quality, guaranteed service levels, premium performance, or other contractual service tiers. Importantly, SLA terminology alone was not sufficient for inclusion in this category; the evidence had to establish a financial relationship between the service-level commitment and the corresponding value-capture mechanism. This distinction ensured that technical QoS requirements were not automatically interpreted as monetisation.

Together, Lease/Rental/Wholesale Access, Usage/Unit-Based Pricing, Marketplace/Auction/Resource Trading, and SLA/Premium/Tiered Charging accounted for 28 of the 35 direct-monetisation relationships, or 80% of the total. The concentration of evidence in these four categories suggests that the most developed monetisation pathways in the reviewed literature are associated with converting network capabilities into accessible resources, measurable service units, market-traded assets, or differentiated service commitments.

Less frequent primary mechanisms included Generic Service Charging/Billing, identified in 3 relationships, and Subscription/Recurring Fees, identified in 2 relationships. Generic charging was retained only where an explicit payment relationship was evident but the source did not specify a sufficiently distinctive tariff structure to support a more precise mechanism. Subscription evidence, by contrast, required an identifiable recurring payment basis rather than the mere presence of an “as-a-Service” label.

The remaining primary mechanisms appeared only once each. Licensing/Software Fees were identified in one relationship associated with NFV-related experimentation and service provisioning, where software access and hosted virtualised functions were linked to fixed or pay-per-use licensing arrangements and hosting charges [75]. One-Time Implementation/Setup Fees were also represented by one relationship, in which an Open RAN business-case model included one-off charges for dedicated enterprise and industrial network implementations. The relevant scenario explicitly models a network

built for an industrial customer using Open RAN and assigns a one-time implementation price, although the value remains a modelled business-case assumption rather than realised commercial revenue [79].

Two additional taxonomy categories—Revenue Sharing/Commission and Sponsorship/Freemium/Bundling—were retained in the coding framework but did not occur as the primary monetisation mechanism in any of the 35 final direct-monetisation relationships. Their absence from the primary-mechanism distribution should therefore be interpreted as an absence of corresponding evidence in the reviewed corpus rather than as evidence that such models are commercially infeasible.

A further finding concerns the specificity of the identified value-capture mechanisms. Only 3 of the 35 direct-monetisation relationships remained within the generic charging category, while 32 were assigned to a more specific monetisation mechanism. This indicates that most cases classified as direct monetisation were supported by more than a general claim of revenue potential: they specified how a technical resource or service could enter an identifiable transaction relationship.

At the same time, mechanism specificity should not be equated with commercial maturity. Several of the identified pricing, leasing, or marketplace arrangements were developed through conceptual architectures, simulations, or techno-economic models rather than observed as established commercial revenue streams. The results therefore indicate that explicit pathways to value capture have been articulated for a subset of 5G, B5G, and 6G-relevant technical enablers, while the extent to which these mechanisms will be realised at scale remains dependent on future technological, market, and ecosystem development.

This distribution provides the basis for the next stage of the synthesis, which examines how particular value propositions are connected to specific monetisation mechanisms, rather than considering either dimension independently.

5.6 Cross-Synthesis: Technical Enabler, Value Proposition and Value Capture

The cross-synthesis examined how the value propositions identified across the 112 positive paper-technical-enabler relationships were translated into explicit mechanisms of value capture within the 35 direct-monetisation cases. Rather than treating technical enablers, value propositions, and monetisation mechanisms as independent dimensions, this stage of the analysis considered the pathways through which a technical capability becomes economically meaningful and, where sufficiently specified, commercially transactable. Figure 5.4 presents the distribution of value proposition–monetisation relationships across the direct-monetisation evidence.

A first important finding is that explicit value capture was highly concentrated within a limited subset of value propositions. Differentiated/Customizable Services accounted for 11 of the 35 direct-monetisation relationships, Open/Shared Ecosystem Platform for 10, and Flexible/Scalable/On-Demand Provisioning for 9. Together, these three value propositions represented 30 of the 35 direct-monetisation cases, or approximately 85.7%. This suggests that explicit monetisation is most frequently articulated where technical enablers either create differentiated service configurations, make network resources accessible across multiple ecosystem actors, or enable resources to be provisioned dynamically according to demand.

Value Proposition–Monetisation Mechanism Cross-Synthesis Heatmap								
VP / Monetisation	Lease	Usage	Marketplace	SLA	Generic	Subscription	Licensi- ng	One- time
Differentiated/ Customizable	1	3	2	3	1	1	0	0
Open/Shared Ecosystem	6	1	1	0	0	0	1	1
Flexible/On- Demand	3	2	2	1	1	0	0	0
Coverage/Acc ess	0	1	0	0	1	0	0	0
Cost-Efficient Infrastructure	2	0	0	0	0	0	0	0
New Services/Mark et Enablement	0	0	0	0	0	1	0	0
Performance/ QoS/Reliable	0	0	0	0	0	0	0	0
Autonomous/ Adaptive Operations	0	0	0	0	0	0	0	0
Energy- Efficient/Susta inable	0	0	0	0	0	0	0	0

Figure 5.4: Heatmap of value proposition–monetisation mechanism relationships across direct-monetisation evidence.

Note: Cell values indicate the number of paper-technical-enabler relationships associated with each value proposition–monetisation mechanism pathway. Zero values indicate that no corresponding relationship was identified in the reviewed corpus and do not imply that the pathway is theoretically or commercially infeasible.

The strongest individual pathway in the cross-synthesis was Open/Shared Ecosystem Platform → Lease/Rental/Wholesale Access, which appeared in 6 evidence relationships. This pattern reflects configurations in which technical resources or infrastructure become accessible to actors beyond the original infrastructure owner through leasing, rental, or wholesale arrangements. More broadly, virtualised and open network environments facilitate multi-actor value networks in which infrastructure, network functions, and service capabilities can be made available across organisational boundaries rather than remaining vertically integrated within a single operator. The same value proposition was also associated with usage-based pricing, marketplace/resource trading, licensing, and one-time implementation fees, indicating that open and shared architectures can support more than one form of value capture. Examples within this broader category include licensing and hosting arrangements for virtualised network functions and experimentation services, as well as one-time enterprise implementation charges in modelled Open RAN business cases [75], [79].

A different pattern emerged for Differentiated/Customizable Services, where monetisation was distributed across a wider range of mechanisms. The most frequent pathways were SLA/Premium/Tiered Charging and Usage/Unit-Based Pricing, with 3 relationships each, followed by Marketplace/Auction/Resource Trading, with 2 relationships. Leasing, generic charging, and subscription-based mechanisms were also present. This diversity indicates that service differentiation does not correspond to a single pricing model. Instead, the same underlying capability to tailor network characteristics can be commercialised through premium service levels, measurable consumption units, negotiated or dynamically traded resources, or recurring service relationships.

Network Slicing is particularly important within this pattern because its combination of isolation, programmability, elasticity, and service differentiation supports several alternative forms of productisation. Sliced resources have been represented as dynamically traded assets with differentiated unit prices, while emerging intent-based service environments extend similar principles toward composite services negotiated according to technical, economic, and SLA-related constraints [60], [65]. These cases illustrate how a common technical foundation can generate more than one pathway from service differentiation to value capture.

Flexible/Scalable/On-Demand Provisioning exhibited a similarly diverse monetisation profile. Its most frequent mechanism was Lease/Rental/Wholesale Access, with 3 relationships, while Usage/Unit-Based Pricing and Marketplace/Auction/Resource Trading each accounted for 2 relationships. SLA-related and generic charging mechanisms appeared once each. This pattern is consistent with the economic logic of dynamically provisioned resources: flexibility becomes monetisable when capacity can be rented, consumed in measurable units, or reallocated through a market according to changing demand.

Several representative technical pathways demonstrate this relationship. Elastic cloud-network slices can be requested, managed, and sublet to other tenants, thereby connecting dynamic resource provisioning to leasing-based value capture [64]. Similarly, on-demand edge-computing capacity can be linked to task-level consumption and pricing, transforming dynamically positioned computing resources into measurable service units [68]. These examples show that the commercial relevance of flexibility does not originate from “on demand” provisioning alone, but from the subsequent productisation of that flexibility into an identifiable and chargeable resource or service.

The remaining value propositions were considerably less represented within direct monetisation evidence. Coverage/Access Extension accounted for 2 direct-monetisation relationships, divided between usage-based pricing and generic service charging. Satellite and NTN-related evidence illustrates how expanded connectivity can be converted into measurable consumption, for example through modelled traffic-based or price-per-GB arrangements [76]. Cost-Efficient Infrastructure and Operations also accounted for 2 direct-monetisation relationships, both associated with leasing or wholesale-type mechanisms. This indicates that cost efficiency can coexist with direct value capture where infrastructure-sharing or inter-operator access relationships are explicitly commercialised, although most cost-efficiency evidence in the wider corpus remained within business/economic value rather than direct monetisation.

This contrast is analytically important. Cost-Efficient Infrastructure and Operations was the second most frequent value proposition across the entire 112- relationship evidence base, with 23 relationships, yet only 2 of these contained an explicit monetisation mechanism. By comparison, Differentiated/Customizable Services contained direct monetisation in 11 of its 20 relationships, and Flexible/Scalable/On-Demand Provisioning in 9 of 15. The frequency of a value proposition therefore does not necessarily indicate how readily that value can be transformed into an identifiable transaction mechanism. Some technical capabilities primarily improve the internal economics of network provision, whereas others are more readily productised into externally chargeable services or resources.

The absence of direct monetisation evidence for Performance/QoS/Reliable Services, Autonomous/Adaptive Network Operations, and Energy-Efficient/Sustainable Networking provides a further illustration of this distinction. These value propositions were present within the broader positive evidence base but were not associated with a primary monetisation mechanism among the 35 direct-monetisation relationships. This should not be interpreted as evidence that such capabilities cannot generate revenue. Rather, within the reviewed corpus, their economic contribution was more frequently articulated through improved service quality, automation, efficiency, or operational performance than through a separately specified transaction mechanism.

Overall, the cross-synthesis suggests that productisation can function as an important intermediary between technical capability and explicit value capture. Technical characteristics such as bandwidth, latency, security, isolation, and other service-level parameters become economically more actionable when they can be configured, measured, and packaged as identifiable commercial offerings [80]. Rather than monetising connectivity only as a relatively homogeneous service, this process enables technically differentiated capabilities to be converted into service units that can be leased, priced according to usage or duration, linked to service-level commitments, or incorporated into higher-level service offerings [75],[80].

Network Slicing provides the clearest illustration of this transition because logically isolated and configurable resources can be transformed into differentiated service-oriented offerings, including Network-as-a-Service configurations. More generally, however, the cross-synthesis indicates that productisation is not limited to a single technology or monetisation mechanism. The same underlying technical capability may support different commercial configurations depending on how it is packaged, positioned within the value network, and combined with complementary resources or services [75].

This distinction helps explain why Network Slicing is more extensively represented in the direct-monetisation evidence than most other technical enablers. Its architectural characteristics facilitate the abstraction, isolation, allocation and configuration of network resources, allowing these resources to be transformed into identifiable service offerings and, in some cases, commercially exchanged. Other

enablers may generate substantial technical or economic value while remaining more deeply embedded within the infrastructure or operating model and therefore less readily productised as separately transactable offerings.

The results therefore support a distinction between two related but different pathways of business-model contribution. In the first, a technical enabler creates indirect economic value by improving cost efficiency, performance, coverage, flexibility, automation, or operational viability. In the second, the enabled capability undergoes sufficient productisation to become the basis of a direct value-capture mechanism, such as leasing, usage-based charging, marketplace trading, subscription, licensing, or premium service-level charging. The two pathways are not mutually exclusive; rather, direct monetisation represents a more specific stage in which technically enabled value is converted into an explicit economic transaction.

Accordingly, the cross-synthesis does not indicate deterministic relationships between particular value propositions and monetisation mechanisms. The observed combinations represent recurring evidence pathways within the reviewed corpus, not causal laws or universally applicable business-model configurations. Nevertheless, their recurrence provides evidence that 5G-, B5G-, and emerging 6G-relevant technologies contribute to business-model innovation not only by creating technical performance improvements, but also by enabling new forms of service productisation, resource exchange, and value capture.

5.7 Discussion of RQ2 Findings: From Technical Enablement to Value Capture

5.7.1 Value creation is broader than direct monetisation

The RQ2 findings reveal a clear distinction between technical enablement, business value creation, and direct monetisation. Although the reviewed literature contains numerous examples in which technical enablers contribute to economically relevant outcomes, substantially fewer relationships specify an explicit mechanism through which that value is captured through a transaction. Of the 112 positive paper-technical-enabler relationships, 77 were associated with business or economic value without a sufficiently explicit monetisation mechanism, while 35 contained direct monetisation evidence.

This distinction is important for the interpretation of 6G business-model research. Technical improvements such as lower deployment cost, higher resource efficiency, greater flexibility, wider coverage, improved automation, or enhanced service performance may strengthen the economic feasibility of a business model without themselves becoming separately chargeable products or services. The commercial significance of a technical enabler therefore cannot be assessed solely by asking whether the technology generates an identifiable revenue stream. In many cases, its contribution lies in altering the cost structure, service capability, operational flexibility, or market feasibility of a broader business configuration.

The value-proposition distribution reinforces this interpretation. Open/shared ecosystem platforms, cost-efficient infrastructure and operations, differentiated services, and flexible or on-demand provisioning accounted for the large majority of the positive RQ2 evidence. However, these propositions exhibited very different monetisation profiles. Cost efficiency, for example, was frequently linked to business value but only rarely to a direct transaction mechanism. By contrast, differentiated services and flexible provisioning were more often associated with explicit value capture. This suggests that different technical capabilities occupy different positions within the business-model logic: some primarily improve the internal economics of provision, whereas others can be more readily exposed to customers or ecosystem participants as commercially distinct offerings.

The findings therefore caution against equating technical capability with monetisation. A technology may be highly significant to the viability of a future business model even when its contribution is indirect. Conversely, the presence of revenue-oriented terminology does not necessarily establish that the focal technology itself is being monetised. This distinction is particularly relevant in complex 6G architectures, where multiple technical components may jointly support a service while the actual transaction takes place at another architectural or business layer.

5.7.2 Productisation as an intermediary between capability and value capture

A central interpretation emerging from RQ2 is that productisation can function as an important intermediary between technical capability and direct value capture. Technical properties become commercially actionable when they can be configured, measured, packaged, accessed, or exchanged as identifiable services or resources.

The cross-synthesis illustrates this process particularly clearly. Direct monetisation was concentrated in three value propositions: Differentiated/Customizable Services, Open/Shared Ecosystem Platform, and Flexible/Scalable/On-Demand Provisioning. Together, these propositions accounted for 30 of the 35 direct-monetisation relationships. The associated value-capture mechanisms were dominated by leasing or wholesale access, usage-based pricing, marketplace or resource trading, and SLA- or premium-based charging.

These patterns suggest that monetisation becomes more explicit when technical resources can be transformed into commercial objects. Such objects may take the form of an access right, an allocated network resource, a measurable unit of consumption, a differentiated service commitment, a licensed capability, or a tradable service component. The technical feature itself is therefore not necessarily what is sold. Rather, the enabled capability is converted into a form that can enter a contractual or market relationship.

This interpretation is consistent with the service-oriented direction identified elsewhere in the reviewed literature. Virtualised and programmable network environments allow infrastructure and network functions to be separated conceptually from their physical implementation and exposed through more modular service arrangements [75], [80].

Productisation therefore represents a bridge between engineering capability and business-model design: it determines how a technical resource becomes something that another actor can request, consume, lease, trade, subscribe to, or pay a premium to receive.

Importantly, this pathway should not be interpreted as deterministic. The same technical capability may support different commercial configurations depending on ownership, ecosystem structure, customer requirements, regulatory conditions, and complementary services. Productisation is therefore better understood as an enabling process through which a technical capability may become commercially transactable, rather than as an automatic consequence of technological development.

5.7.3 Network Slicing as the clearest articulation of technical monetisation

Network Slicing provides the strongest illustration of this productisation logic. It accounted for 21 of the 35 direct-monetisation relationships and therefore represented the most extensively articulated technical enabler in relation to explicit value capture within the reviewed corpus.

Its prominence is closely connected to the way slicing transforms network resources into logically isolated, configurable, and differentiated service environments. Unlike a capability that remains embedded within general infrastructure, a network slice can be defined around identifiable service

requirements and allocated to specific tenants, users, applications, or vertical industries. This facilitates a relatively direct transition from technical configuration to commercial offering.

The literature demonstrates several variations of this logic. Slice-as-a-Service models allow tenants to request and manage end-to-end slices and, in some cases, sublet associated resources or services [64].

Other models treat sliced resources as dynamically priced or traded assets, with infrastructure providers, MVNOs, and users participating in resource-allocation and pricing relationships [65].

More generally, slicing supports differentiated service levels that can be associated with usage-based, premium, SLA-linked, leasing, or marketplace arrangements [62], [64], [65].

The significance of Network Slicing should nevertheless be interpreted carefully. Its dominance in the direct-monetisation evidence does not establish that it is inherently more profitable or strategically more important than other 6G-relevant technologies. Rather, it indicates that the literature has developed a comparatively explicit vocabulary and modelling tradition for describing how slicing resources can be packaged and exchanged commercially.

Other enablers, including MEC/Edge Computing, NFV, NTN, Open RAN, Network Softwarisation, and Intent-Based Networking, also exhibit identifiable monetisation pathways, but these occur less frequently. In many of these cases, the economic contribution is instead expressed through lower costs, increased deployment flexibility, improved performance, wider coverage, or more efficient resource utilisation. Their comparatively lower direct-monetisation frequency may therefore reflect differences in commercial abstraction and productisation, rather than lower economic relevance.

5.7.4 From articulated 5G transactions to prospective 6G value configurations

The generational comparison provides a further important interpretation. Direct monetisation mechanisms were more frequently articulated within the 5G-precursor evidence than within the 6G-oriented evidence. This difference should not be interpreted as evidence that 6G has lower commercial potential. It is better understood as a difference in the specificity and maturity of the available commercial evidence.

The 5G literature contains a larger body of studies in which technical abstractions and service configurations are sufficiently developed to support explicit questions concerning who pays, what resource is exchanged, how access is priced, and how revenue is generated. Leasing, subletting, resource trading, usage-based charging, and differentiated service pricing are therefore comparatively visible in the 5G-precursor evidence [64], [65].

The 6G-oriented evidence is more frequently concerned with identifying future capabilities, deployment economics, ecosystem configurations, and the technical or techno-economic feasibility of emerging architectures. Fully-Decoupled RAN, THz-related transport configurations, and NTN architectures, for example, are often evaluated through cost, investment, coverage, or infrastructure-efficiency considerations rather than through independently specified customer-facing transaction mechanisms [70], [71], [72].

This does not mean that explicit monetisation is absent from 6G research. Softwarised service architectures and intent-based marketplaces already provide examples of more explicit future transaction structures involving resource provision, service exchange, pricing constraints, payments, and SLA-linked financial mechanisms [60], [73].

These cases indicate that monetisation concepts are beginning to extend beyond conventional operator-to-customer charging towards more complex multi-actor exchange environments.

The broader pattern is therefore one of commercial articulation developing alongside technological and ecosystem maturity. 5G provides relatively mature examples of how programmable network capabilities can be packaged into transactions, while 6G research increasingly explores how similar principles may be extended to more distributed, software-based, intelligent, and multi-stakeholder environments. Earlier-generation evidence is consequently useful as an antecedent, but it should not be treated as proof that identical pricing or value-capture mechanisms will transfer unchanged into 6G.

5.7.5 Implications for emerging 6G business models

Taken together, the RQ2 findings suggest that the business significance of future-network technologies depends less on the existence of individual technical capabilities than on how those capabilities are translated into economically meaningful service configurations.

This has two related implications. First, business-model innovation in 6G is likely to involve not only new technologies but also new ways of exposing, combining, measuring, and allocating technical resources. Network capabilities that remain embedded within infrastructure may primarily generate economic value through efficiency or performance improvements. Capabilities that can be abstracted and productised, by contrast, may support more explicit revenue mechanisms through leasing, usage-based charging, differentiated service tiers, subscriptions, marketplaces, or other forms of exchange.

Second, the increasingly platform-oriented and multi-actor character of future networks means that value capture may occur across several organisational layers rather than through a single operator-to-customer transaction. Open/shared ecosystem platforms were the most frequent value proposition in the RQ2 synthesis and were associated with several different monetisation mechanisms. This suggests that the commercial role of technical enablers increasingly depends on how they are positioned within broader value networks involving infrastructure providers, service providers, platforms, vertical industries, and other ecosystem participants.

RQ2 therefore complements the business-model archetypes identified in RQ1. The archetypes describe how commercial activity may be organised, whereas RQ2 explains one of the mechanisms through which those models can become economically actionable: technical capabilities must first create an identifiable form of value and, where direct monetisation is intended, must subsequently be productised into a resource or service that can enter an explicit transaction.

The resulting pathway can be expressed as:

Technical Enabler → Technical Capability → Value Proposition → Productisation → Value-Capture Mechanism

The key implication is that the transition from technical possibility to commercial value is not automatic. A technically advanced network may support substantial economic value without generating an independent revenue stream, while a monetisable service requires more than technical performance alone. It requires a sufficiently clear commercial object, an identifiable customer or ecosystem participant, and a workable mechanism through which value can be exchanged and captured. In this sense, the central challenge for 6G business-model development is not simply to create new technical capabilities, but to determine which capabilities can be meaningfully configured, packaged, exchanged, and integrated into viable service and ecosystem arrangements.

5.8 Direct Answer to Research Question 2

The final evidence synthesis indicates that several 6G-relevant technical enablers are linked to new value propositions and monetisation or value-capture mechanisms, although the specificity of these relationships varies considerably across technologies. Across the 112 positive paper-technical-enabler relationships spanning 5G-precursor, B5G, cross-generation, and 6G-oriented research, 35 cases (31.3%) contained an explicit monetisation mechanism attributable to the corresponding technical enabler, while the remaining 77 demonstrated business or economic value without an equally explicit mechanism of value capture. The findings therefore indicate that technical enablers are more widely associated with the creation of value propositions than with directly articulated monetisation mechanisms. Improvements in performance, cost efficiency, flexibility, coverage, automation, or ecosystem participation may generate substantial business value without necessarily becoming independently chargeable products or services.

Among the identified technologies, Network Slicing demonstrated the most explicit and recurrent relationship between technical capability, value proposition, and monetisation. It accounted for 21 of the 35 direct-monetisation relationships, representing 60% of all explicitly monetised cases in the final synthesis. Its commercial relevance is closely related to the ability to transform logically isolated, configurable, and differentiated network resources into identifiable service offerings adapted to customer- or application-specific requirements. The reviewed evidence illustrates several forms of value capture based on this capability, including slice purchase and premium differentiated services, leasing and subletting of slice resources, usage- or resource-based pricing, Slice-as-a-Service arrangements, and other forms of differentiated service charging. Rather than treating connectivity only as a homogeneous service, slicing therefore enables network characteristics such as bandwidth, latency, isolation, and service quality to be configured and packaged into more granular commercial offerings [62], [64], [75], [80].

This finding suggests that productisation can function as an important intermediary between technical capability and direct value capture. Technical characteristics become more readily monetisable when they can be transformed into measurable, configurable, accessible, or tradable service units. The cross-synthesis supports this interpretation: Differentiated/Customizable Services, Open/Shared Ecosystem Platform, and Flexible/Scalable/On-Demand Provisioning together accounted for 30 of the 35 direct-monetisation relationships (85.7%). Correspondingly, the most frequent value-capture mechanisms were Lease/Rental/Wholesale Access, Usage/Unit-Based Pricing, Marketplace/Auction/Resource Trading, and SLA/Premium/Tiered Charging. The relationship is not one-to-one: the same underlying capability may support different commercial models depending on how it is packaged, positioned within the value network, and combined with complementary services [67],[69].

Other technical enablers exhibited a broader mixture of direct and indirect business value. MEC/Edge Computing, NFV, and NTN each showed explicit monetisation evidence in a smaller subset of cases, while Heterogeneous Networks, Network Softwarisation, Small Cells/Ultra-Densification, Open RAN, and Intent-Based Networking also displayed identifiable value-capture mechanisms at lower frequencies. At the same time, technologies such as Massive MIMO, mmWave, SDN, cloud-native architectures, orchestration, AI/ML-enabled networking, THz communications, and other infrastructure-oriented enablers were more commonly associated with value creation through improved performance, resource efficiency, cost reduction, flexibility, automation, coverage, or deployment viability rather than through independently specified transaction mechanisms [61], [66], [67]. These findings indicate that technical enablers do not contribute uniformly to business-model innovation: some can be directly

transformed into chargeable network resources or services, whereas others primarily improve the economic or technical conditions under which broader commercial offerings become viable.

The generation-based analysis further suggests that the articulation of value capture evolves with technological maturity. Direct monetisation mechanisms were identified in 35.8% of the 5G-precursor evidence compared with 18.5% of the 6G-oriented evidence. This difference should not be interpreted as evidence of lower commercial potential for 6G. Rather, the 5G literature more frequently specifies relatively concrete mechanisms such as leasing, resource trading, usage-based charging, and service-level differentiation, whereas emerging 6G research more commonly focuses on prospective value propositions, future ecosystem structures, techno-economic feasibility, and increasingly distributed service architectures. Distributed cloud architectures, virtualised service-based networks, specialised network slicing, open interfaces, and AI/ML-enabled orchestration are increasingly discussed as foundations for more modular, service-oriented, and multi-actor 6G configurations, in which network capabilities can be dynamically combined and exposed across different architectural layers [45].

Overall, the evidence suggests that these relationships are articulated through a progressive pathway in which technical capabilities create specific forms of value, are subsequently productised into identifiable service or resource configurations, and, in a smaller subset of cases, are linked to explicit mechanisms of value capture:

Technical Enabler → Technical Capability → Value Proposition → Productisation → Value-Capture Mechanism

Within the reviewed literature, direct monetisation was most clearly articulated where a technically enabled capability could be translated into an identifiable commercial object—such as an access right, resource allocation, measurable service unit, differentiated service commitment, licensed capability, or tradable asset. Where such productisation is absent, technical enablers may still generate substantial indirect economic value by reducing costs, improving resource utilisation, extending coverage, increasing flexibility, or enabling new services and ecosystem configurations. The evidence therefore suggests that the business significance of 6G-relevant technologies lies not simply in their technical performance, but in how effectively those capabilities can be configured, packaged, exchanged, and integrated into viable value networks and service offerings.

5.9 RQ2-Specific Limitations

The interpretation of RQ2 should account for the heterogeneity and maturity of the underlying evidence. The reviewed literature included empirical studies, techno-economic models, conceptual and foresight research, industry-oriented cases, and secondary literature. Consequently, the identification of an explicit monetisation mechanism does not necessarily indicate observed commercial adoption. Proposed architectures, simulated pricing arrangements, and modelled business cases were interpreted as evidence that an attributable pathway to value capture had been articulated, rather than as evidence of realised or scalable market revenue.

A further limitation concerns the attribution of business or economic outcomes to individual technical enablers. Many publications examined multiple technologies within broader architectures or service ecosystems, making it difficult in some cases to isolate the contribution of a single enabler. Relationships for which attribution remained insufficiently defensible were therefore retained as contextual or boundary evidence rather than included in the positive synthesis. The resulting evidence base should accordingly be interpreted as a conservative representation of technical-business relationships that could

be supported at enabler level, rather than as an exhaustive account of every possible interaction between technical capabilities and economic outcomes.

The quantitative findings also represent the distribution of evidence within the reviewed corpus rather than measures of market size, profitability, commercial adoption, causal effectiveness, or the intrinsic strategic importance of particular technologies. For example, the concentration of direct-monetisation evidence around Network Slicing indicates that explicit value-capture mechanisms are more extensively articulated for slicing within the reviewed literature; it does not demonstrate that Network Slicing is economically superior to other 6G-relevant enablers.

Low-frequency categories should be interpreted particularly cautiously. Fully Decoupled RAN and Intent-Based Networking were each represented by only one positive paper-technical-enabler relationship, meaning that they were retained as emerging candidates rather than used to support strong comparative conclusions. Similarly, the B5G Transition category contained only two positive relationships, making its apparent direct monetisation share unsuitable for substantive comparison with the larger generation categories.

Evidence from earlier network generations also should not be interpreted as proof that equivalent commercial mechanisms will persist unchanged in 6G. Evidence from 5G and B5G was used to identify already articulated forms of service productisation, business value, and monetisation that may provide antecedents for future-network business models. The 6G-oriented evidence, by contrast, remains more prospective in several areas. Cross-generation comparisons should therefore be understood as reflecting differences in the specificity and articulation of the available evidence, rather than as direct forecasts of future 6G commercial performance.

Finally, the distinction between business/economic value and direct monetisation reflects the evidential requirements of the analytical framework rather than a claim that indirect value is commercially less important. Technical enablers may contribute substantially to economic viability through cost reduction, improved resource utilisation, flexibility, performance, coverage, automation, or ecosystem participation without being transformed into separately chargeable products or services. Direct monetisation therefore represents a more specific subset of technical–business evidence in which an identifiable transaction or value-capture mechanism could be attributed to the focal enabler.

Taken together, these limitations mean that the RQ2 findings should be interpreted as a structured account of how the reviewed literature links technical capabilities to value propositions and mechanisms of value capture, rather than as evidence of realised market performance or deterministic relationships between particular technologies and commercial outcomes.

6. RQ3: Methodological Approaches and Validation Strategies

6.1 Analytical sample

The RQ3-specific screening of the 218-paper corpus identified 107 studies containing a substantive 5G-, B5G-, or 6G-related business, economic, value-network, or commercial configuration that met the methodological inclusion criteria. The remaining 111 publications were excluded from the RQ3 analysis because the business dimension was either absent, contextual, or secondary to a predominantly technical analytical object.

Among the 107 included studies, 72 (67.3%) were classified as 5G precursor studies, 10 (9.3%) as B5G transition studies, 17 (15.9%) as 6G-oriented studies, and 8 (7.5%) as cross-generation studies, as summarised in Table 6.1.

Table 6.1: Composition of the RQ3 analytical sample

Generation	n	% of included studies
5G	72	67.3%
B5G transition	10	9.3%
6G	17	15.9%
Cross-generation	8	7.5%
Total	107	100.0%

Note: Because the number of 5G and 6G studies differed substantially, the direct comparison between the two generations was based primarily on within-generation percentages rather than raw frequencies. B5G-transition and cross-generation studies were retained as distinct categories and were not reassigned to either generation.

6.2 Methodological approaches

Across the full analytical sample, methodological approaches were relatively evenly divided between quantitatively oriented and conceptual work. Quantitative approaches accounted for 36 studies (33.6%), while 35 studies (32.7%) were classified as conceptual-analytical. Qualitative and mixed methods approaches each accounted for 18 studies (16.8%). The methodological breadth of the literature is also reflected at study level, ranging from qualitative future-oriented sensemaking of 5G business-model uncertainty and testbed-informed mixed analysis of deployment and business-model implications to 6G scenario construction combining documentary evidence and expert input, and broader conceptual ecosystem analysis [81].

The generational comparison revealed differences in methodological composition between the 5G and 6G subsets (Figure 6.1). Among the 72 5G studies, 27 (37.5%) employed a quantitative approach, followed by 21 (29.2%) conceptual-analytical studies, 15 (20.8%) mixed-methods studies, and 9 (12.5%) qualitative studies.

In contrast, the 6G-oriented literature was predominantly conceptual-analytical. Nine of the 17 6G studies (52.9%) were classified as conceptual-analytical, compared with 3 (17.6%) quantitative studies. Qualitative approaches accounted for 4 studies (23.5%), while only 1 study (5.9%) employed mixed methods. Nevertheless, quantitative assessment was not absent from the 6G literature, with some studies already combining techno-economic modelling, simulation, and scenario comparison for emerging 6G infrastructures [82].

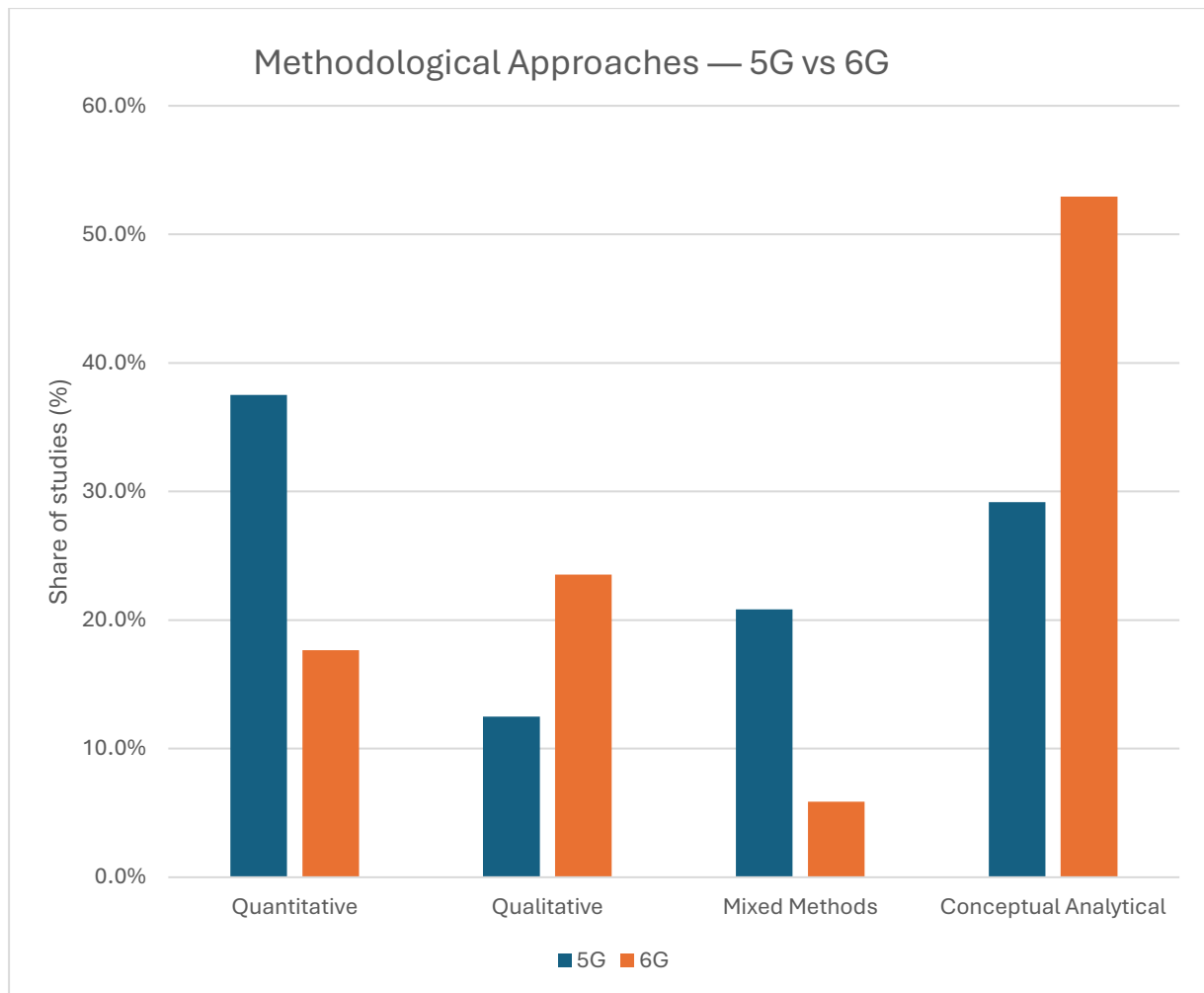


Figure 6.1: Methodological approaches in 5G and 6G business-model studies

Overall, the 5G subset was more strongly represented by quantitative and mixed-methods designs, whereas the 6G subset was more strongly represented by conceptual-analytical and qualitative approaches.

6.3 Evaluation strategies and evaluation targets

The methodological comparison was extended by examining the specific strategies used to analyse or evaluate the business-model propositions identified in the included studies. As individual publications could employ more than one evaluation strategy, this dimension was treated as multi-label and the resulting percentages therefore do not sum to 100%. Because not all analytical strategies constituted validation in the strict sense, they are reported here collectively as evaluation strategies.

Across the full analytical sample, business-model or value-network analysis was the most frequently identified strategy, appearing in 95 of the 107 studies (88.8%). This was followed by comparative analysis in 77 studies (72.0%), scenario analysis in 61 (57.0%), and evidence-synthesis or document analysis in 50 (46.7%). More quantitatively oriented strategies included techno-economic modelling in 40 studies (37.4%) and simulation or numerical analysis in 28 (26.2%). The comparison between 5G and 6G revealed both substantial commonalities and clear differences in the strategies employed (Figure 6.2). Business-model or value-network analysis was highly prevalent in both groups, occurring in 62 of 72 5G studies (86.1%) and 16 of 17 6G studies (94.1%). Comparative analysis was similarly common, accounting for 72.2% of 5G studies and 70.6% of 6G studies.

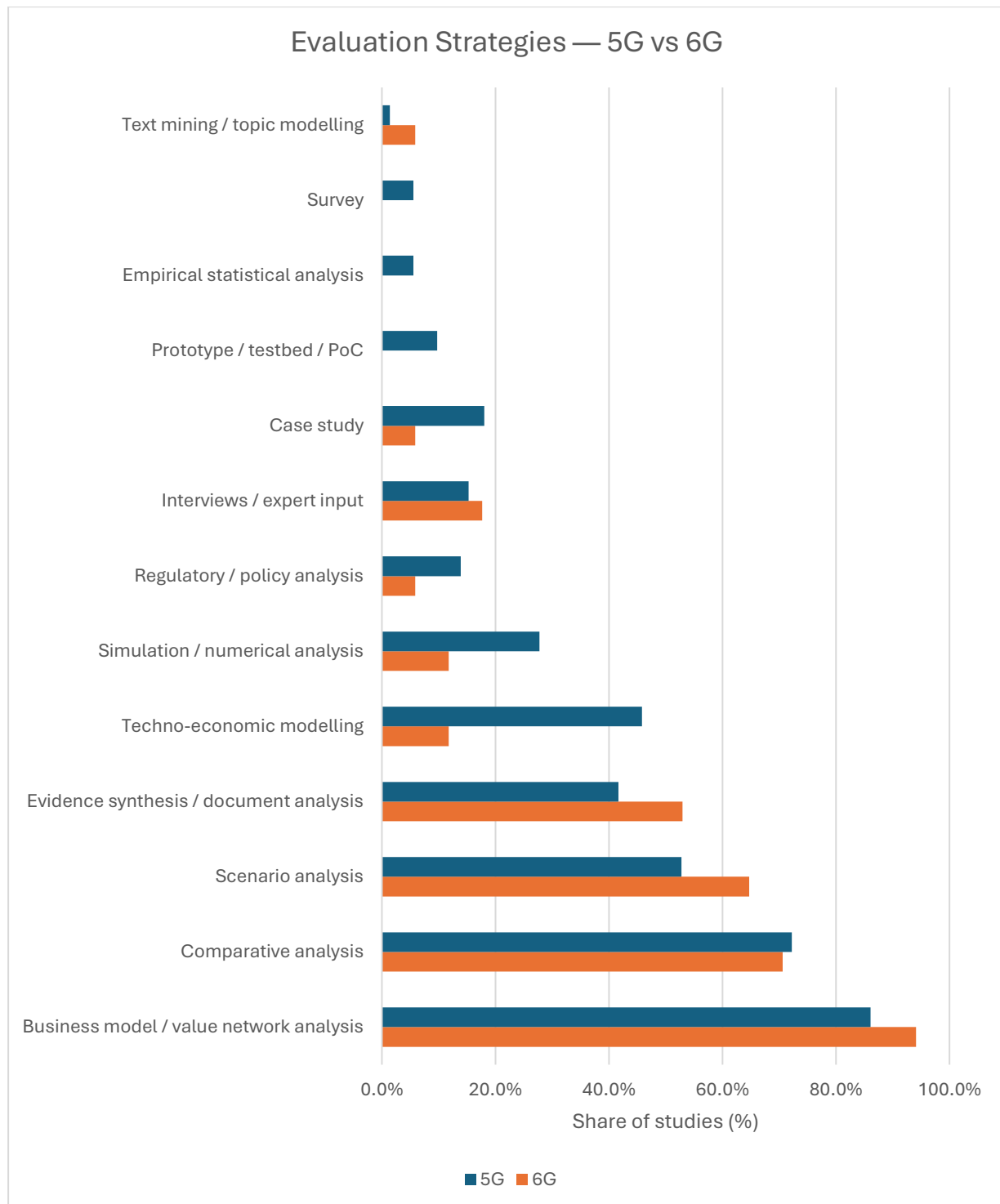


Figure 6.2: Evaluation strategies used in 5G and 6G business-model studies

More pronounced differences appeared in quantitatively oriented evaluation strategies. Techno-economic modelling was employed in 33 5G studies (45.8%) compared with only 2 6G studies (11.8%). Likewise, simulation or numerical analysis appeared in 20 5G studies (27.8%) but only 2 6G studies (11.8%). Case-study analysis was also more frequent in the 5G literature, representing 18.1% of 5G studies compared with 5.9% of 6G studies. Prototype, testbed, or proof-of-concept activity was identified as an evaluation strategy in 7 5G studies (9.7%), whereas no corresponding case was observed among the 6G-oriented studies.

By contrast, scenario-based and document-based approaches were relatively more prominent in the 6G literature. Scenario analysis was used in 11 of 17 6G studies (64.7%), compared with 38 of 72 5G studies (52.8%). Evidence-synthesis or document analysis occurred in 52.9% of 6G studies and 41.7% of 5G studies. Interviews or expert input showed relatively little difference between the two groups, accounting for 15.3% of 5G studies and 17.6% of 6G studies. This orientation is reflected in 6G studies that construct future service scenarios from documentary evidence and expert input, synthesise the emerging 6G ecosystem conceptually, or compare alternative value-network configurations for prospective local 6G deployments [83], [84], [85].

A small subset of publications presented substantive business-model analysis without an explicitly executed evaluation. This applied to 4 5G studies (5.6%) and 2 6G studies (11.8%). As described in the methodology, this status was recorded separately and was not treated as an evaluation strategy in Figure 6.2.

The analysis also examined what aspects of the business model were evaluated. Evaluation targets were coded independently from evaluation strategies and could likewise receive multiple labels within the same study, as summarised in Table 6.2.

Business-model structure was a dominant target in both generations, occurring in 88.9% of 5G studies and 94.1% of 6G studies. Technical feasibility supporting the business model was also almost equally represented, at 48.6% and 47.1%, respectively.

Table 6.2: Evaluation targets by generation

Evaluation target	5G n (%)	6G n (%)
Business-model structure	64 (88.9%)	16 (94.1%)
Economic viability	47 (65.3%)	8 (47.1%)
CAPEX/OPEX/TCO	27 (37.5%)	3 (17.6%)
Revenue/profitability	42 (58.3%)	2 (11.8%)
Pricing/resource allocation	27 (37.5%)	4 (23.5%)
Market acceptance/demand	38 (52.8%)	4 (23.5%)
Stakeholder/value network	52 (72.2%)	16 (94.1%)
Technical feasibility supporting BM	35 (48.6%)	8 (47.1%)
Value capture/monetisation	38 (52.8%)	14 (82.4%)

Note: Evaluation targets were multi-label; percentages therefore do not sum to 100%.

The main differences concerned the economic and market dimensions of evaluation. Revenue and profitability were examined in 58.3% of 5G studies but only 11.8% of 6G studies, representing the largest percentage-point difference observed between the two generations among the coded evaluation targets. Economic viability was also more frequently assessed in 5G studies (65.3% vs. 47.1%), as were CAPEX/OPEX/TCO (37.5% vs. 17.6%) and market acceptance or demand (52.8% vs. 23.5%). This stronger investment- and viability-oriented emphasis is reflected in 5G techno-economic studies that explicitly evaluate deployment configurations through measures such as CAPEX, OPEX, TCO, demand, cost allocation, and financial viability [86], [87].

Conversely, 6G studies placed greater emphasis on ecosystem-level and value-configuration dimensions. Stakeholder or value-network relationships were examined in 94.1% of 6G studies compared with 72.2% of 5G studies, while value capture or monetisation was addressed in 82.4% of 6G studies compared with 52.8% of 5G studies. This high prevalence reflects attention to value-capture configurations and proposed monetisation mechanisms and should not be interpreted as evidence that profitability or realised revenue had been demonstrated. In the 6G-oriented literature, this ecosystem-level emphasis is illustrated by analyses that map stakeholder roles, technical and business interfaces, charging relationships, benefits, constraints, and value-capture structures across alternative future deployment configurations [85].

Overall, 5G studies used more techno-economic, numerical, and market-facing forms of evaluation, whereas 6G studies relied more strongly on scenario, synthesis, and ecosystem-oriented assessment.

6.4 Business/Economic Evaluation Maturity and Technical Evidence

The maturity of the business and economic evidence varied considerably across the included studies. Across the full analytical sample, 35 studies (32.7%) were classified as conceptual only, 25 (23.4%) as analytically modelled, 17 (15.9%) as simulated, 3 (2.8%) as case-based, and 27 (25.2%) as empirically assessed. No study met the criteria for experimentally demonstrated business/economic maturity.

The comparison between 5G and 6G revealed a higher concentration of conceptual business-model evaluation in the 6G literature. Among the 72 5G studies, 21 (29.2%) were classified as conceptual only, while 22 (30.6%) were analytically modelled. A further 11 studies (15.3%) evaluated business or economic outcomes through simulation, 2 (2.8%) were case-based, and 16 (22.2%) were empirically assessed.

In the 6G-oriented literature, 8 of the 17 studies (47.1%) remained at the conceptual-only level. Analytically modelled studies represented 17.6% (3/17), while only 1 study (5.9%) was classified as simulated. One further study (5.9%) was case-based, and 4 studies (23.5%) were empirically assessed.

Empirical assessment was present at similar descriptive proportions in the two subsets (22.2% of 5G studies and 23.5% of 6G studies), although the substantially smaller 6G sample warrants caution in interpreting this similarity. This finding is important because it indicates that the 6G literature cannot be characterised simply as lacking empirical evidence. Rather, the distinction lies in the larger concentration of 6G studies at the conceptual stage and the lower prevalence of analytical modelling and simulation.

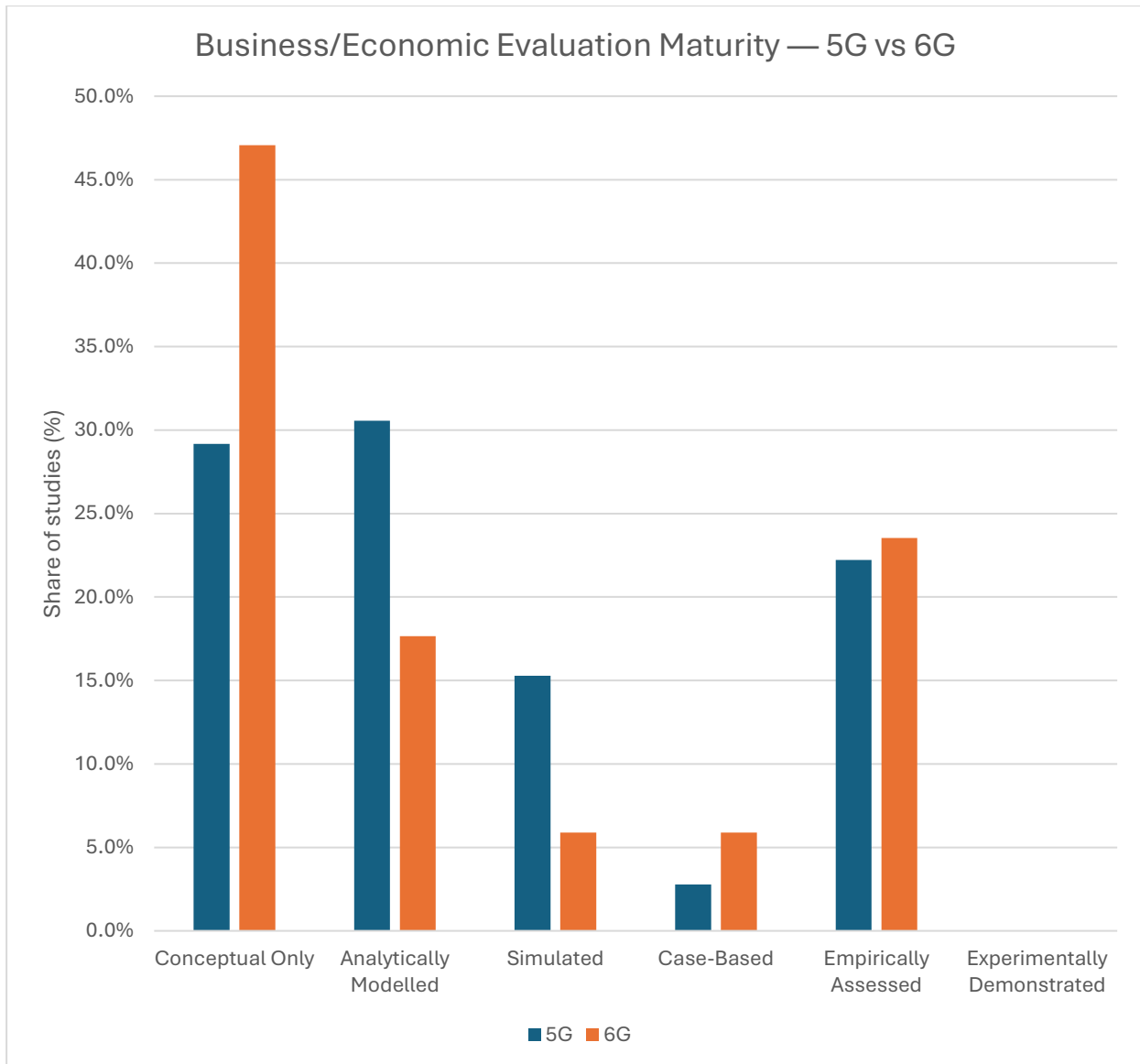


Figure 6.3: Business/economic evaluation maturity in 5G and 6G studies

The main maturity contrast was the higher concentration of conceptual-only studies in the 6G literature and the greater prevalence of analytical modelling and simulation in the 5G literature. This pattern is consistent with the comparatively established techno-economic evaluation tradition surrounding 5G, while quantitative techno-economic assessment is also beginning to be applied to selected emerging 6G configurations [88].

No study in the full analytical sample reached experimentally demonstrated business/economic maturity; technical prototypes or testbeds alone did not satisfy this criterion.

6.5 Technical evidence supporting business-model evaluation

The technical evidence associated with the included studies was analysed independently from business/economic maturity. Across the 107 studies, 62 (57.9%) contained no primary technical evidence. Analytical technical models were identified in 20 studies (18.7%), simulations in 16 (15.0%), prototype or testbed evidence in 8 (7.5%), and field-trial or deployment evidence in 1 study (0.9%).

The generational comparison revealed a stronger presence of primary technical evidence in the 5G literature (Figure 6.4). Among 5G studies, 37 of 72 (51.4%) contained no primary technical evidence. Analytical technical models were present in 17 studies (23.6%), simulation evidence in 9 (12.5%), and prototype or testbed evidence in 8 (11.1%). One 5G study (1.4%) contained field-trial or real-deployment evidence.

By comparison, 13 of the 17 6G-oriented studies (76.5%) contained no primary technical evidence. Analytical models and simulations each appeared in 2 studies (11.8%), while no 6G-oriented study in the analytical sample contained prototype/testbed or field-deployment evidence.

More advanced forms of primary technical evidence were concentrated in the 5G subset: prototype/testbed evidence and the sole field-trial/deployment case occurred only in 5G, while the absence of primary technical evidence was more common in the 6G subset.

Figures 6.3 and 6.4 confirm that business/economic maturity and technical evidence are distinct dimensions. Advanced technical evidence could coexist with a conceptual business proposition, while empirical business/economic assessment did not necessarily require a technical prototype or field deployment.

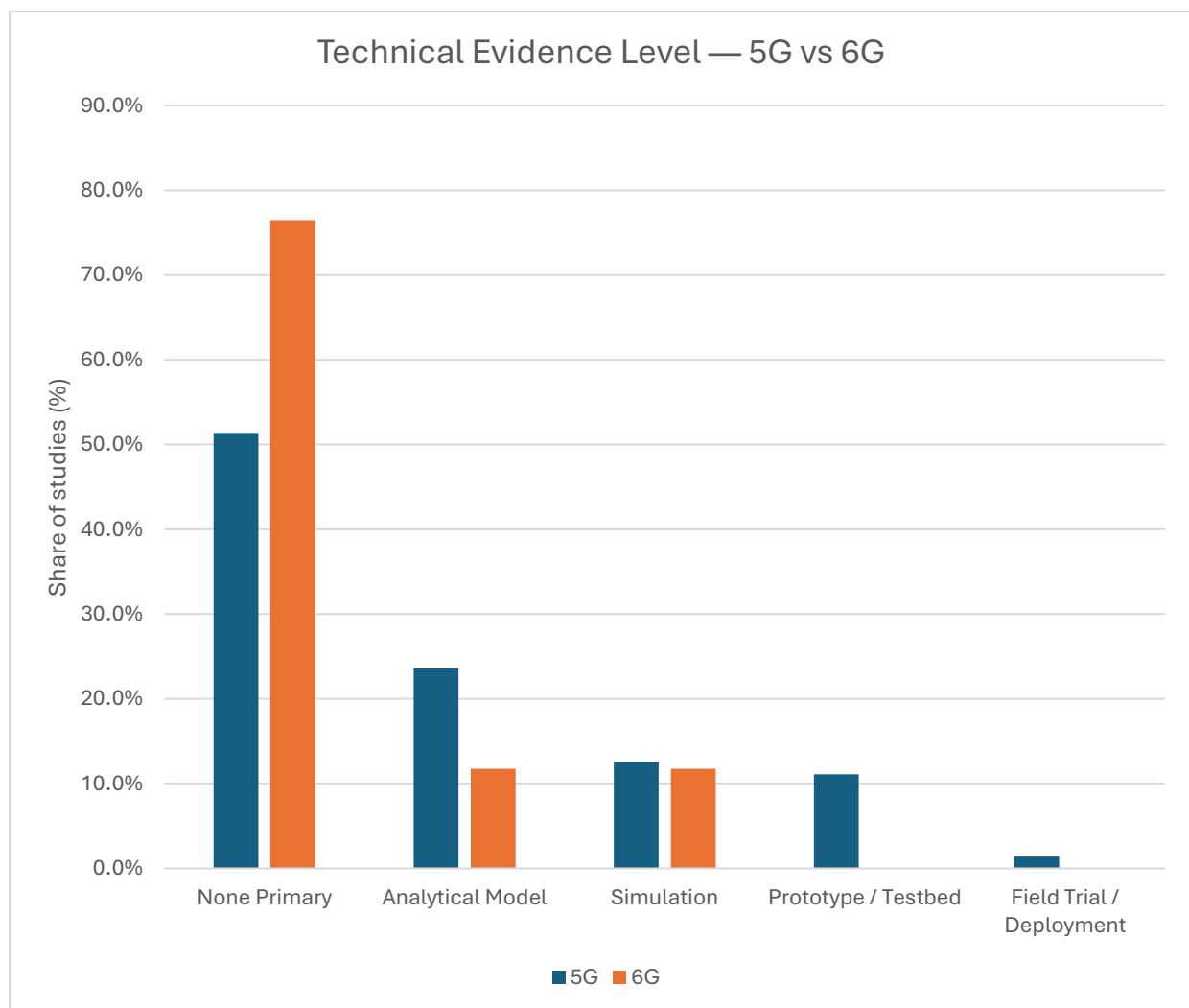


Figure 6.4: Technical evidence levels in 5G and 6G studies

6.6 Discussion of RQ3 Findings: Evaluation and Evidence Maturity

6.6.1 From operational evaluation in 5G to prospective evaluation in 6G

The results are best interpreted as differences in the stage and object of business-model inquiry rather than as a simple contrast between validated and unvalidated research.

This pattern suggests that the two literatures are addressing different stages of business-model development. The 5G literature more frequently treats the underlying technology and service environment as sufficiently specified to support operational questions such as whether a deployment can be economically viable, what its cost structure is, how revenue may be generated, and whether demand can support the proposed business case. Consequently, techno-economic modelling, numerical analysis, and simulation appear more prominently in 5G-related research, as illustrated by studies evaluating network-slicing and private-network configurations through investment, demand, cost, TCO, ROI, and sensitivity analysis [86], [87].

The 6G literature, by contrast, more often addresses questions concerning how future ecosystems may be structured, which actors may participate, where value may be created and captured, and how emerging technological capabilities could support new commercial configurations. Scenario analysis, evidence synthesis, and conceptual business-model or value-network analysis are therefore particularly relevant to this literature, including studies that construct future 6G service scenarios or compare alternative value-network configurations for emerging local deployments [83], [85].

Rather than indicating an absence of business-model evaluation, the findings suggest a different evaluation orientation, centred more strongly on prospective ecosystem design than on established operating economics.

6.6.2 Differences in evaluation focus

The evaluation-target pattern supports this lifecycle interpretation. 5G research more often operationalises commercial feasibility through concrete cost, revenue, profitability, and demand questions, whereas 6G research more often explores actor roles, value-network structures, and monetisation mechanisms before stable financial parameters are available.

Value capture and monetisation therefore should not be read as evidence that profitability has already been quantitatively established. In many 6G studies, these concepts identify possible revenue mechanisms, platform relationships, ecosystem roles, or future service exchanges at a configurational stage, before prices, demand assumptions, and cost structures are sufficiently stable for a complete commercial assessment.

The contrast is also visible in the specific targets of evaluation. The 5G literature more frequently examines economic viability through CAPEX, OPEX, TCO, revenue, profitability, pricing, and market-acceptance measures, whereas the 6G literature places comparatively greater emphasis on stakeholder relationships, business-model structure, and value capture. This does not imply that 6G studies demonstrate stronger commercial performance. Rather, it indicates that they more often investigate how value might be organised and distributed within proposed future configurations before the underlying financial parameters have become sufficiently stable for rigorous profitability assessment.

6.6.3 Business/economic maturity and technical evidence are distinct

A central implication of RQ3 is that business/economic evaluation maturity and technical evidence should remain analytically separate. No study in the analytical sample reached experimentally

demonstrated business/economic maturity; the presence of a technical prototype or testbed alone was not sufficient to satisfy this criterion. The generational distribution of technical evidence reinforces this distinction. Primary technical evidence was more visible in the 5G literature, including prototype, testbed, and limited field-based evidence, whereas the 6G-oriented subset was more frequently characterised by the absence of primary technical demonstration or by analytical and simulation-based evidence. This pattern is consistent with the earlier developmental stage of many 6G propositions and suggests that technical feasibility, business-model structure, and commercial viability are often being explored at different levels of maturity rather than progressing in parallel.

This distinction is visible particularly in the 5G literature, where prototype and testbed evidence are present but do not automatically correspond to experimentally demonstrated business-model evaluation. A technical system may successfully demonstrate network functionality, service delivery, latency performance, resource allocation, or another engineering capability while the associated pricing model, revenue logic, stakeholder incentives, or commercial uptake remains conceptual or analytically modelled. This distinction is also visible in 5G research drawing on testbed environments or pre-commercial experimentation platforms, where technical demonstration does not by itself establish experimentally demonstrated business-model viability [75], [105].

This separation also helps interpret the 6G findings. The higher proportion of 6G studies with no primary technical evidence is consistent with the generally prospective character observed across the methodological results, but it does not mean that these studies provide no evaluative evidence. Several 6G studies still use empirical business/economic evidence, interviews, documentary sources, or other forms of systematic assessment. The main difference lies in the relatively limited presence of primary technical demonstration and formal economic modelling within the 6G-oriented subset.

This finding also highlights why validation terminology requires care. Simulation, analytical modelling, scenario analysis, expert assessment, case evidence, and technical testbeds all provide legitimate forms of evaluation, but they answer different questions and provide different levels of evidence. Describing all such approaches simply as “validation” risks obscuring what has actually been tested.

6.6.4 Implications for future 6G business-model research

The results point to several methodological opportunities for future 6G business-model research. As proposed business ecosystems and service configurations become more specified, future work could complement conceptual and scenario-based analysis with stronger techno-economic modelling, explicit cost and revenue structures, demand assumptions, pricing analysis, and sensitivity testing [82], [88].

A second opportunity concerns the connection between ecosystem design and economic feasibility. The strong 6G emphasis on stakeholder networks and value capture provides a useful foundation, but future studies could increasingly translate these proposed configurations into measurable financial relationships. For example, identified actor roles and value flows could be linked to explicit revenue allocation, cost-sharing mechanisms, investment requirements, or alternative pricing structures.

Third, stronger integration between technical and business evaluation would be valuable. Technical simulation or demonstration can provide evidence regarding whether a service proposition is technically feasible, while business/economic analysis can assess whether the actors involved have sufficient incentives to deploy, operate, and adopt it. Assessing these dimensions jointly, while continuing to distinguish them analytically, would provide a more comprehensive evaluation of emerging 6G business models.

A further methodological priority is greater alignment between the object of evaluation and the evidence used to support it. Scenario analysis and conceptual ecosystem modelling are appropriate for exploring early-stage 6G configurations, but stronger commercial claims will progressively require explicit assumptions concerning demand, costs, pricing, investment, and stakeholder incentives. Similarly, technical simulation or prototyping should not be treated as a substitute for business/economic evaluation when the research question concerns commercial viability. Future studies would therefore benefit from evaluation designs in which technical, economic, and ecosystem evidence are linked while their distinct evidential roles remain transparent.

Finally, future studies could move beyond prospective commercial logic toward more direct testing of business mechanisms where suitable environments become available. This would include pricing arrangements, stakeholder incentives, service uptake, transaction mechanisms, and other value-capture processes rather than relying on technical demonstrations as indirect evidence of commercial viability. Together, these steps could support a gradual transition in 6G business-model research from prospective configuration towards increasingly testable commercial propositions.

6.7 Direct Answer to RQ3

RQ3 shows that 5G- and 6G-related business-model research employs a broad range of methodological approaches and evaluation strategies, but with different emphases across technological generations. The 5G literature is more strongly represented by quantitative and mixed-methods approaches and makes greater use of techno-economic modelling, simulation, and numerical analysis. It also more frequently evaluates operational commercial dimensions such as economic viability, CAPEX/OPEX/TCO, revenue and profitability, pricing, and market demand.

The 6G-oriented literature is more strongly represented by conceptual-analytical and qualitative approaches and places comparatively greater emphasis on scenario analysis, evidence synthesis, stakeholder ecosystems, value networks, and proposed mechanisms of value capture. Business/economic evaluation also remains more frequently at the conceptual stage, while primary technical demonstration is less prevalent than in the 5G literature.

The comparison therefore indicates a difference between the more operational and techno-economic evaluation profile characteristic of the 5G literature and the more prospective and ecosystem-oriented profile observed in emerging 6G research. However, this distinction should not be interpreted as a simple contrast between empirically validated 5G research and unevaluated 6G research. Empirical business/economic assessment occurs in both subsets, while different analytical strategies provide evidence concerning different aspects of a business-model proposition.

A further finding is that technical evidence and business/economic validation are distinct dimensions. Technical simulation, prototype, testbed, or deployment evidence does not by itself demonstrate commercial viability, pricing validity, market adoption, or value capture. No study in the analysed literature met the defined threshold for experimentally demonstrated business/economic validation.

6.8 RQ3-Specific Limitations

The interpretation of RQ3 should account for the unequal size of the generation-specific evidence bases. The direct comparison involved 72 5G studies but only 17 6G-oriented studies. Although within-generation percentages were used to reduce the effect of unequal group sizes, the smaller 6G subset means that individual publications can have a comparatively larger influence on the observed

proportions. The reported differences should therefore be interpreted descriptively rather than as statistically inferred differences between the wider 5G and 6G literatures.

The methodological categories also necessarily simplify a heterogeneous body of research. Individual studies frequently combined several analytical techniques, data sources, or evaluation objectives. A single primary methodological approach was assigned to characterise the dominant study design, while evaluation strategies and evaluation targets were treated as multi-label dimensions. The resulting categories therefore provide a structured comparative representation of the literature rather than an exhaustive description of every methodological component within each publication.

The business/economic maturity framework should likewise not be interpreted as a general hierarchy of research quality. Conceptual, scenario-based, qualitative, and ecosystem-oriented studies may provide valuable evidence for emerging business configurations even when they do not include formal financial modelling or experimental commercial testing. The maturity classification instead indicates the form and directness of the business or economic evidence available for the proposition being examined.

A further limitation concerns the distinction between technical and business/economic evidence. Technical simulations, prototypes, testbeds, and deployments can establish the feasibility or performance of an enabling technology, but they do not independently demonstrate the viability of associated pricing structures, revenue mechanisms, stakeholder incentives, market demand, or commercial adoption. Conversely, empirical business or ecosystem evidence can be generated without an accompanying technical prototype. The two evidence dimensions should therefore be interpreted separately.

Finally, much of the 6G-oriented literature remains prospective because the underlying technologies, architectures, markets, and ecosystem configurations are still developing. The greater prevalence of conceptual-analytical, scenario-based, and ecosystem-oriented approaches in the 6G subset should consequently be interpreted in relation to the developmental stage of the literature rather than as evidence of lower methodological quality. The comparison captures the evaluation strategies currently represented in the reviewed corpus and does not imply that the observed methodological profile will remain unchanged as 6G technologies and markets mature.

7. RQ4: Barriers, risks, and open challenges to the realisation of 6G business models

The RQ4-specific reassessment of the 218-publication corpus identified 91 studies containing primary evidence of barriers, risks, or open challenges with a sufficiently attributable business-model consequence. A further 21 publications were retained as supporting or contextual evidence, while 106 were excluded from the primary RQ4 synthesis. The primary analytical sample therefore comprised 91 studies and 586 distinct paper-barrier relationships.

7.1 Overall distribution of barriers

The findings show that obstacles to future mobile-network business models are strongly multidimensional. Economic and commercial barriers were the most prevalent domain within the reviewed primary evidence base.

Economic and commercial barriers appeared in 83 of the 91 primary studies (91.2%). Organisational and ecosystem barriers were identified in 72 studies (79.1%), technical barriers in 69 studies (75.8%), and regulatory or institutional barriers in 57 studies (62.6%).

Because individual publications could contain barriers belonging to more than one domain, these categories are not mutually exclusive, and the percentages do not sum to 100%. The prevalence of the barrier domains across the primary evidence base is presented in Figure 7.1.

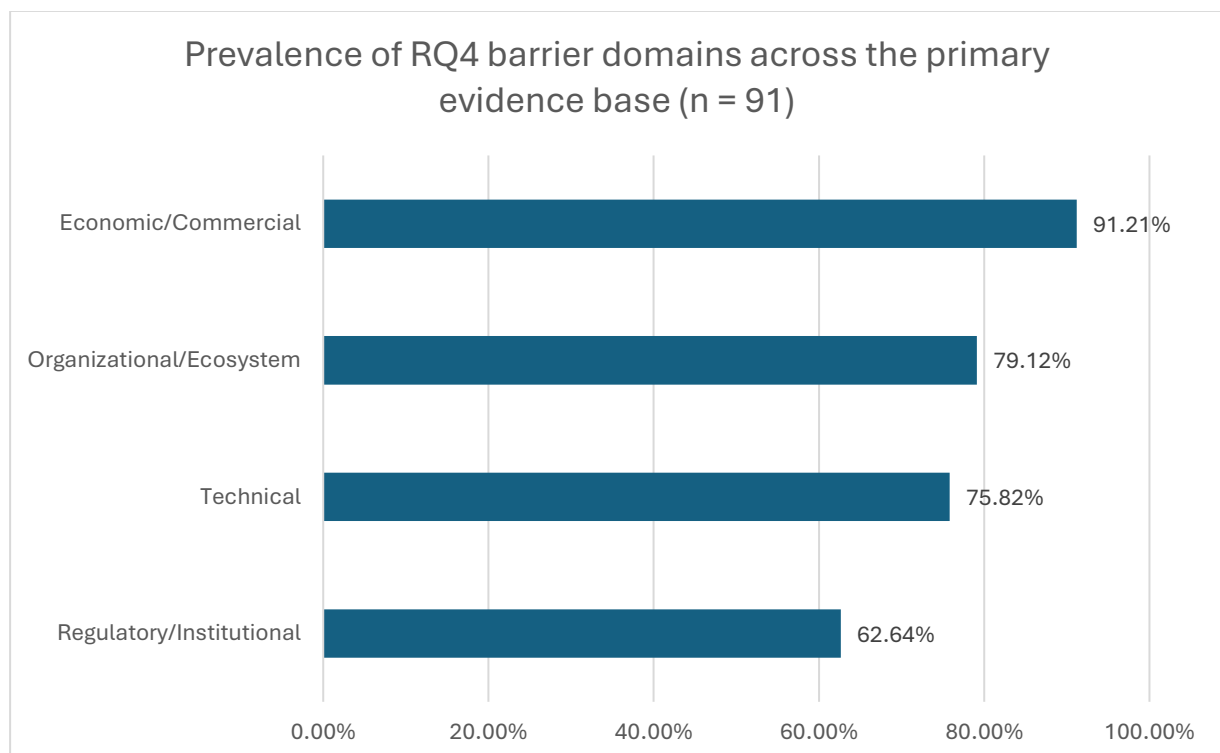


Figure 7.1: Prevalence of RQ4 barrier domains across the primary evidence base (n = 91).

The most frequently observed individual barrier was multi-stakeholder coordination and collaboration, identified in 49 studies (53.8%). This was closely followed by high capital expenditure, total cost of ownership, or other upfront investment requirements in 48 studies (52.7%), and uncertain return on investment or payback in 47 studies (51.6%). Pricing, revenue, and monetisation uncertainty occurred in 41 studies (45.1%), while demand, ARPU, adoption, or willingness-to-pay uncertainty appeared in 40 studies (44.0%).

Other recurrent barriers included problems in allocating costs and revenues among ecosystem participants, spectrum and coverage limitations, uncertainty regarding actor roles and governance structures, high operating and maintenance costs, and market-structure or affordability constraints.

Taken together, these findings indicate that the commercialisation challenge surrounding future mobile networks cannot be reduced to whether 6G technology can technically be implemented. Recent cross-generational foresight evidence reinforces this multidimensional interpretation. Future-network evolution is occurring under simultaneous pressure from continued infrastructure investment requirements, declining or constrained connectivity revenues, difficulties in introducing new services and business models, regulatory complexity and shortages of specialized capabilities. Commercialisation therefore depends on the co-evolution of technology, market structures, organisational capabilities and regulatory frameworks rather than on network performance alone [89].

Rather, the literature frames realisation as a problem of simultaneously establishing economic viability, commercially sustainable value capture, coordinated ecosystem participation, technically reliable service delivery, and regulatory feasibility. To support higher-level interpretation, the coded barriers were consolidated into seven non-mutually exclusive analytical themes, as presented in Figure 7.2.

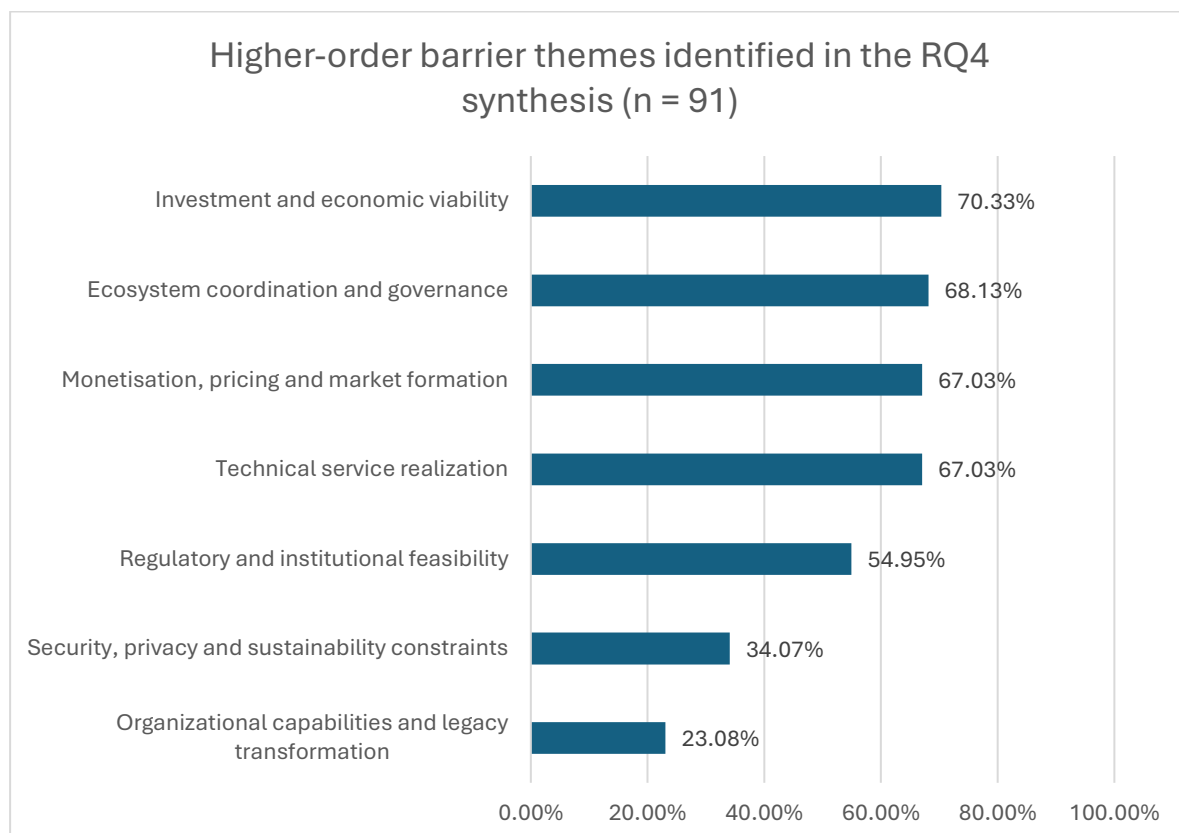


Figure 7.2: Higher-order barrier themes identified in the RQ4 synthesis (n = 91).

Note: A publication may contribute to multiple themes.

7.2 Investment and economic viability

The first higher-order theme concerns investment and economic viability, identified in 64 studies (70.3%).

High upfront expenditure emerges as one of the most persistent barriers across deployment settings. The investment requirements associated with network infrastructure, densification, spectrum, edge computing, private networks, non-terrestrial networks, network virtualization and new radio technologies are frequently discussed alongside uncertain demand and uncertain long-term returns.

The problem is therefore not simply the absolute amount of investment required. Rather, the literature repeatedly identifies a mismatch between the timing and certainty of costs and the timing and certainty of revenues. Infrastructure and technology expenditure generally occurs before customer demand, adoption levels and willingness to pay can be established with confidence. Operational market evidence illustrates this mismatch clearly. High deployment expenditure can coincide with declining average revenue per user, limited growth in connectivity revenues and increasing operating-cost pressure, progressively weakening the viability of conventional operator models. These conditions strengthen the economic rationale for alternative arrangements based on infrastructure sharing, neutral hosting and more flexible value-chain configurations [90].

Consequently, high capital expenditure frequently interacts with ROI and payback uncertainty. This pattern is particularly visible in rural and underserved-area deployments, where network infrastructure may be expensive relative to the size and purchasing power of the addressable market. Similar tensions occur in private networks, network slicing, Open RAN, edge infrastructure and non-terrestrial network configurations. This tension is reinforced by quantitative evidence showing that limited or declining ARPU, substantial infrastructure expenditure and spectrum-licensing costs can make coverage-oriented deployment commercially unattractive, particularly in sparsely populated or underserved areas. The viability of future-network deployment therefore depends not only on technological cost reductions but also on policy choices affecting spectrum expenditure, infrastructure availability and the economics of extending coverage beyond high-demand markets [91].

The implication is that technical feasibility does not guarantee commercial feasibility. A network architecture or service configuration may perform successfully from an engineering perspective while still failing to satisfy the investment thresholds required by operators, infrastructure providers or other ecosystem participants.

This distinction is especially relevant to 6G, where several proposed technological capabilities remain associated with substantial infrastructure, computing, energy and integration requirements before mature markets have been established.

7.3 Monetisation, pricing, and market formation

A second major theme relates to monetisation, pricing, and market formation, identified in 61 studies (67.0%).

Future mobile-network architectures create possibilities for business models such as Network-as-a-Service, Slice-as-a-Service, neutral-host infrastructure, local and private networks, data marketplaces, satellite-terrestrial integration and capability-based services. However, the existence of a technically differentiated service does not automatically determine how that service should be priced or how the resulting value should be captured.

The literature therefore identifies persistent uncertainty over:

- pricing mechanisms;
- revenue streams;
- customer willingness to pay;
- cost allocation;
- wholesale charges;
- revenue-sharing arrangements;
- affordability;
- and the distribution of economic value among participating actors.

In network slicing and shared-infrastructure configurations, for example, multiple organizations may contribute resources to the same service. The business case depends not only on total revenue but on whether costs, revenues, risks and incentives can be allocated in a manner that encourages all necessary participants to remain within the ecosystem. Multi-operator service models further demonstrate that viability depends on the distribution of economic incentives between participating actors. Resource-access charges, network-capacity decisions, service quality, user subscription choices and the resulting profits of infrastructure and service providers are interdependent. A technically feasible sharing arrangement may therefore remain commercially unstable unless the contractual and pricing structure produces acceptable outcomes for all actors involved [92]. Economic modelling of differentiated 5G services further indicates that business-model viability depends on the joint configuration of pricing, service quality, resource-sharing rules and market structure. User adoption responds to both price and perceived QoS, while operator profitability depends on the resulting subscription levels and allocation of network resources. This implies that monetisation mechanisms cannot be designed independently from the technical configuration through which differentiated services are delivered [93].

Similarly, data-oriented and platform-oriented models depend on the existence of sufficient buyers, sellers and users to create economically valuable network effects. Platform-oriented services may therefore face a critical-mass problem during commercialisation. Adoption on one side of a platform can affect service availability, data generation and participation on other sides, while weak initial adoption can reduce service value and discourage further infrastructure investment. Conversely, sufficient participation can create reinforcing feedback between users, services, data availability, revenues and additional investment [94].

This creates a recurring commercialisation problem: technical capabilities must be translated into a stable mechanism for value capture.

Moqaddamerad and Tapinos, for example, show how 5G uncertainty can require established telecommunications organizations to reconsider customer segments, value propositions, organisational structures and revenue mechanisms as part of business-model innovation. Their study explicitly connects technological, market, investment and regulatory uncertainty with the difficulty of developing viable future business models [81].

7.4 Ecosystem coordination and governance

A third major barrier cluster concerns ecosystem coordination and governance, identified in 62 studies (68.1%).

This theme is particularly important because multi-stakeholder coordination was the single most frequently identified individual barrier in the entire synthesis.

Unlike traditional vertically integrated telecommunications models, many proposed 5G and 6G business configurations require collaboration among several independent actors. These may include mobile-network operators, infrastructure providers, cloud providers, vertical industries, application developers, equipment vendors, data providers, local or private operators, satellite operators, regulators and public authorities.

This fragmentation creates several related challenges.

First, responsibilities for investment, infrastructure provision, service management and customer relationships may be unclear. Second, the actor creating technological value may not necessarily be the actor able to capture the corresponding economic value. Third, participants may have different incentives regarding infrastructure sharing, openness, data exchange or investment. These coordination difficulties become particularly visible when services span previously separate network domains. Integrated terrestrial and non-terrestrial configurations require resource negotiation among multiple operators while also raising questions concerning interfaces, equipment compatibility, pricing, risk allocation and responsibility for service failure. Increasing the number of independent participants can therefore raise transaction and coordination costs unless dedicated governance or intermediary mechanisms are established [95].

Consequently, the literature frequently identifies:

- unclear actor roles;
- governance ambiguity;
- asymmetric bargaining power;
- conflicting incentives;
- difficulties in establishing partnerships;
- data and resource-sharing concerns;
- and coordination costs across organisational boundaries.

The realisation of a future-network business model therefore depends not only on designing an attractive value proposition but also on constructing a stable value network in which the required actors can identify acceptable roles, responsibilities and returns. Proposed brokerage arrangements illustrate one possible response to this problem by centralizing resource negotiation and reducing the number of direct relationships that individual operators must manage. However, such mechanisms introduce their own requirements concerning platform governance, pricing design, regulatory oversight and the allocation of operational and financial risk, showing that coordination problems are often redistributed rather than eliminated [95].

This issue becomes increasingly significant in 6G-oriented ecosystem studies, where the anticipated expansion of platforms, local networks, non-terrestrial systems, AI-enabled services and cross-industry collaboration further increases the number and diversity of relevant stakeholders.

7.5 Technical barriers and their business-model consequences

Technical barriers were identified in 69 studies (75.8%). However, the RQ4 analysis deliberately distinguished between generic technical research problems and technical limitations that directly affect business-model realisation.

The higher order theme of technical service realisation, which combines performance, reliability, orchestration, interoperability, spectrum/resource constraints and technological maturity, appeared in 61 studies (67.0%).

Several mechanisms translate technical problems into business-model consequences. Insufficient reliability or QoS can lead to failure to meet contractual service-level agreements. Complex orchestration and virtualization can increase operating and maintenance requirements. Lack of interoperability can raise integration costs and restrict the ability to replicate a service across different vendors, platforms or jurisdictions. Direct 6G techno-economic evidence illustrates this mechanism at the transport-network level. Proprietary equipment can create integration complexity, restrict procurement alternatives and force operators to trade off higher initial investment against future scalability. More open and modular architectures may reduce these constraints, but their commercial value depends on whether improved interoperability, flexibility and scalability translate into sufficiently lower acquisition and operating costs [96]. The same mechanism appears in network and service separation strategies, where interoperability, network management and QoS must remain effective across organisational boundaries. Achieving this separation may itself require additional investment in technologies and processes, illustrating how architectural openness can create business opportunities while simultaneously introducing integration and coordination costs [89].

Spectrum and coverage limitations can require additional infrastructure investment. Immature technologies can postpone commercialisation or increase investment uncertainty. This mechanism is illustrated clearly in work on virtualised future networks. Cao et al. describe how softwarisation in 6G can lead to performance degradation and increased maintenance costs, while simultaneously modelling contractual relationships among telecommunications providers, service providers and paying users. In this configuration, technical service failure can directly affect payment, compensation and service viability [73].

A related study on NFV-enabled vehicular networks explicitly links physical network failures and service interruptions to contractual service guarantees and financial penalties between virtual-network service providers and users [97].

The systematic review by Quan et al. similarly notes that the commercial development of NFV has not progressed as expected partly because important virtualization, cloudification, reliability and service-orchestration challenges remain unresolved. The study explicitly frames these issues as obstacles to large-scale commercial adoption rather than solely as engineering research problems [98].

These findings support an important interpretation of RQ4: technical limitations function as business-model barriers when the reviewed literature links them to consequences such as cost, contractual risk, service quality, scalability, adoption, or deployment uncertainty.

7.6 Security, privacy, and sustainability constraints

Security, privacy and sustainability constitute another cross-cutting barrier theme, identified in 31 studies (34.1%) when cybersecurity, privacy/data governance and energy/environmental constraints are considered jointly.

Security and privacy issues can influence business-model realisation through reduced customer trust, increased compliance requirements, contractual liability and limitations on data sharing or monetisation.

These concerns become particularly important for business models involving distributed infrastructure, network slicing, AI, edge computing, data marketplaces, autonomous systems and multi-actor ecosystems. Prospective 6G use-case analysis shows that these concerns can materialize simultaneously rather than independently. High initial investment, maintenance costs, cyberattack and system-failure exposure, proprietary-platform concentration, emerging legal obligations and workforce reskilling requirements can all affect the viability of the same service configuration. This reinforces the view that trustworthiness, sustainability and economic feasibility need to be evaluated jointly during business-model design [99].

Data-driven business models introduce an additional tension between value capture and regulatory compliance. As IoT ecosystems expand, data may pass through multiple intermediaries whose roles as data controllers, processors or service providers can change across the value chain, complicating responsibility and accountability. Consent enforcement, interoperability between heterogeneous systems, transparency over data use and cross-border differences in privacy regulation can therefore restrict the collection, exchange and monetisation of data on which such business models depend [100].

Energy consumption introduces an additional intersection between technical and economic sustainability. Bolla et al. explicitly argue that the transition toward 5G can substantially increase computing-resource requirements, CAPEX, OPEX and energy consumption. Their proposed framework connects energy efficiency with stakeholder incentives, affordability, mass-market formation and the revenues required to balance telecommunications infrastructure investment [101].

The business-model implications of sustainability are also visible in empirical work on green mobile operators. The green-MNO framework explicitly incorporates cost structures, revenue streams, investment requirements and sustainability targets within the same business-model configuration [58].

Within the reviewed literature, sustainability is not framed solely as an environmental objective. Where energy, resource consumption or environmental obligations alter operating costs, investment requirements, customer acceptance or regulatory exposure, sustainability becomes part of the broader business-model viability problem. At the business-model level, the transition toward sustainability also remains incomplete. Current ecosystem practices are still concentrated primarily on environmental-economic and value-maintaining approaches, while broader mechanisms for sharing sustainable value among stakeholders remain less mature. Achieving sustainability-oriented business models therefore requires coordinated changes not only in resource consumption but also in value creation, delivery, capture and sharing across the ecosystem [102].

7.7 Regulatory and institutional feasibility

Regulatory and institutional factors represent another substantial barrier domain. Regulatory or institutional barriers were present in 57 of the 91 studies (62.6%), while the consolidated higher-order theme of regulatory and institutional feasibility was identified in 50 studies (54.9%).

The most recurrent issues included:

- spectrum licensing and sharing;
- spectrum pricing;
- data and privacy governance;

- competition regulation;
- network-neutrality considerations;
- authorization of local, private or virtual operators;
- infrastructure-sharing rules;
- public support and procurement;
- and differences between national regulatory regimes.

These barriers are particularly important for business models that depart from the conventional nationwide MNO model. Local networks, micro-operators, neutral hosts, private networks, virtual network operators and satellite-integrated models may depend on forms of spectrum access and market authorization that existing telecommunications frameworks were not originally designed to accommodate.

The integrated satellite-terrestrial context demonstrates this problem particularly clearly. Kim and Choi identify spectrum and licensing issues, interoperability between MNOs and satellite network operators, wholesale access, pricing models, data security and legal/regulatory arrangements as conditions affecting the development of B5G-NTN and prospective satellite virtual network operator models [103].

Consequently, regulatory barriers affect more than compliance costs. They can influence who is allowed to participate in the market, which resources they can access, how actors can interconnect, and whether a business model can be replicated across jurisdictions.

7.8 Organisational capabilities and legacy transformation

A smaller but still distinct theme concerns organisational capabilities and legacy transformation, identified in 21 studies (23.1%).

Future-network business models frequently require competencies that differ from those associated with traditional connectivity provision. Operators may need capabilities in cloud platforms, software development, analytics, AI, vertical-industry integration, platform management and ecosystem orchestration. The organisational burden may extend beyond acquiring technical expertise to the systematic retraining and upskilling of personnel required to operate increasingly automated, data-intensive and software-based service environments. These capability requirements introduce additional transition costs and can delay commercialisation where the necessary expertise is scarce or cannot be developed at the same pace as technological change [99].

The transition can therefore require new organisational structures, skills, sales processes and partnership models. Evidence from industrial adoption reinforces this organisational constraint. Companies considering 5G-enabled service transformation identify shortages of relevant expertise and competencies as a major implementation obstacle, alongside the complexity of integrating new network infrastructure with existing architectures, equipment and workflows. These constraints imply that even where new connectivity enables commercially attractive services, firms may be unable to exploit them without simultaneous investment in organisational knowledge, technical skills and complementary infrastructure [104].

At the same time, legacy infrastructure and vendor dependencies may constrain flexibility. Migration from vertically integrated proprietary systems toward more open, virtualised and software-based networks can introduce integration complexity, procurement challenges and dependence on specialized skills.

Table 7.1: Higher-Order Barrier Themes and Their Business-Model Implications

Higher-order theme	Studies, n (%)	Business-model implication
Investment and economic viability	64 (70.3%)	High deployment and lifecycle costs, combined with uncertain demand and returns, weaken investment incentives and may delay or prevent commercially viable rollout.
Ecosystem coordination and governance	62 (68.1%)	Dependence on multiple actors, unclear roles, asymmetric incentives, and data- or resource-sharing frictions hinder the formation of stable value networks and scalable service ecosystems.
Monetisation, pricing and market formation	61 (67.0%)	Uncertain pricing, value-capture mechanisms, cost and revenue allocation, and competitive conditions make it difficult to convert network capabilities into sustainable revenue streams.
Technical service realisation	61 (67.0%)	QoS and SLA constraints, orchestration complexity, interoperability gaps, resource and coverage limitations, and technology immaturity increase cost and risk and may delay commercialisation.
Regulatory and institutional feasibility	50 (54.9%)	Spectrum rules, competition policy, authorization requirements, legal fragmentation, and public-policy design can constrain market entry, infrastructure sharing, and cross-border scalability.
Security, privacy and sustainability constraints	31 (34.1%)	Cybersecurity, privacy, trust, and energy or environmental burdens can increase compliance and operating costs, reduce adoption, and weaken the sustainability of data- and AI-intensive business models.
Organisational capabilities and legacy transformation	21 (23.1%)	Skills gaps, organisational change requirements, and legacy or vendor dependencies can slow the transition toward software, platform, and service-oriented business models.

Note: Higher-order themes are non-mutually exclusive, and a study may contribute to more than one theme. Percentages are calculated against the 91 studies included in the primary RQ4 synthesis. The themes represent an interpretive cross-domain synthesis of the canonical barrier codes and therefore do not correspond one-to-one with the four original barrier domains.

Accordingly, business-model innovation requires not only technological investment but also organisational transformation. The higher-order themes represent an interpretive cross-domain synthesis of the canonical barrier codes and therefore do not correspond one-to-one with the four original barrier domains, as summarised in Table 7.1.

7.9 Differences across 5G, B5G, and Direct 6G Evidence

The generational distribution of the primary evidence base was uneven.

Of the 91 studies:

- 59 (64.8%) were classified as 5G precursor evidence;
- 7 (7.7%) as transitional B5G evidence;
- 14 (15.4%) as direct 6G evidence;

- and 11 (12.1%) as cross-generational evidence.

This distinction is methodologically important and is reflected in the generational comparison presented in Table 7.2.

The 5G literature contains substantially more operational evidence concerning actual deployment costs, investment decisions, customer demand, ARPU, pricing, organisational transformation and commercial adoption. Within the precursor-5G literature, for example, stakeholder coordination appeared in 34 of 59 studies (57.6%), ROI/payback risk in 33 (55.9%), CAPEX/TCO in 32 (54.2%), and demand/adoption uncertainty in 32 (54.2%).

Direct-6G evidence remains comparatively prospective. Among the 14 direct-6G studies, ecosystem coordination remains highly prominent, but greater attention is also given to governance, technological maturity, energy requirements, emerging actor structures and regulatory preparedness.

This difference should not be interpreted as evidence that traditional economic problems such as demand uncertainty will become unimportant in 6G. Instead, it reflects the current maturity of the research field. Commercial 5G experience makes it possible to observe actual investment and adoption problems, whereas much of the 6G literature remains focused on anticipated architectures, ecosystems and service configurations.

Table 7.2: Prevalence of selected barriers across generational evidence categories.

Barrier	5G precursor (n=59)	B5G transition (n=7)	Direct 6G (n=14)	Cross- generation (n=11)
Multi-stakeholder coordination / collaboration	34 (57.6%)	2 (28.6%)	8 (57.1%)	5 (45.5%)
High CAPEX / TCO / upfront investment	32 (54.2%)	4 (57.1%)	6 (42.9%)	6 (54.5%)
ROI / payback / investment risk	33 (55.9%)	2 (28.6%)	6 (42.9%)	6 (54.5%)
Pricing / revenue / monetisation uncertainty	29 (49.2%)	3 (42.9%)	3 (21.4%)	6 (54.5%)
Demand / ARPU / adoption uncertainty	32 (54.2%)	2 (28.6%)	2 (14.3%)	4 (36.4%)
Cost allocation / revenue sharing / incentive economics	22 (37.3%)	1 (14.3%)	3 (21.4%)	2 (18.2%)
Spectrum / resource / coverage constraints	17 (28.8%)	3 (42.9%)	3 (21.4%)	5 (45.5%)
Role / value-chain / governance ambiguity	17 (28.8%)	0 (0.0%)	6 (42.9%)	4 (36.4%)
High OPEX / maintenance / energy cost	16 (27.1%)	3 (42.9%)	6 (42.9%)	0 (0.0%)
Market structure / competition / affordability	19 (32.2%)	0 (0.0%)	3 (21.4%)	2 (18.2%)

Note: Values are reported as n (% within generation). Percentages are calculated separately within each generational evidence category. Comparisons are descriptive because the group sizes are unequal, particularly for the B5G transition evidence (n = 7).

Accordingly, 5G evidence is interpreted in this review as an empirical and operational antecedent to possible 6G commercialisation barriers, rather than as direct evidence that identical market outcomes will necessarily occur under 6G.

7.10 RQ4 synthesis

Overall, the literature suggests that the realisation of proposed 6G business models is best understood as a system-level viability problem rather than a purely technological-readiness problem.

The four barrier domains interact strongly.

Technical limitations can increase capital and operating costs or undermine SLA performance. Higher costs increase investment and payback risk. Investment viability depends in turn on demand, pricing and monetisation. Monetisation frequently requires cooperation and value sharing among several ecosystem participants. Finally, the feasible structure of the ecosystem is influenced by regulation concerning spectrum, data, competition, market entry and infrastructure access.

The findings therefore suggest that resolving individual technical limitations in isolation is unlikely to be sufficient for successful commercialisation.

Instead, viable 6G business models will require the simultaneous alignment of:

technological readiness, economic sustainability, monetisation logic, ecosystem governance, organisational capability, and regulatory support.

This interaction also helps explain why multi-stakeholder coordination emerged as the most frequent individual barrier in the synthesis. The transition toward platform-based, service-oriented, shared, local, virtualised and non-terrestrial network configurations expand both the number of possible revenue opportunities and the number of interdependencies required to realize them.

Thus, the central obstacle identified by RQ4 is not a single technology, regulation, or economic parameter. Rather, it is the challenge of constructing a coherent commercial ecosystem in which technical performance can be translated into sustainable value creation and capture for all actors required to deploy and operate the network.

7.11 Discussion of RQ4 Findings: Barriers to 6G Business-Model Realisation

7.11.1 Business-model realisation as a system-level viability challenge

The RQ4 findings indicate that the realisation of proposed 6G business models should not be understood primarily as a question of technological readiness. Although technical barriers were widely represented, economic/commercial, organisational/ecosystem, and regulatory/institutional constraints were also pervasive across the evidence base. The resulting picture is therefore one of system-level viability, in which commercial realisation depends on the simultaneous alignment of several interdependent conditions rather than on the resolution of any single category of obstacle.

This interpretation is reinforced by the prevalence of the higher-order themes. Investment and economic viability, ecosystem coordination and governance, monetisation and market formation, and technical service realisation all appeared prominently within the primary evidence base. Their coexistence suggests that the barriers affecting future-network business models are rarely isolated. A technical limitation may increase deployment or operating costs; higher costs may worsen investment risk;

uncertain investment returns may depend on demand and pricing; and viable pricing may itself require coordinated participation and value sharing among multiple actors. Regulation can then influence which actors are permitted to participate, what resources they can access, and under what conditions services can be offered.

The significance of this pattern is that commercially viable 6G configurations cannot be inferred from technical feasibility alone. A technically functional service may still lack an acceptable investment case, a sufficiently clear value-capture mechanism, a stable ecosystem of participating actors, or an enabling regulatory environment. Conversely, an attractive commercial proposition may remain unrealised if technical reliability, interoperability, coverage, or orchestration cannot support the promised service characteristics at acceptable cost.

RQ4 therefore extends the distinction already visible in the wider study between technical capability and commercial viability. The literature does not treat these dimensions as interchangeable. Instead, business-model realisation emerges from their alignment.

7.11.2 Investment uncertainty and the monetisation problem

A particularly important finding is the close relationship between investment requirements and monetisation uncertainty. High CAPEX, TCO, operating costs, and uncertain ROI were among the most recurrent barriers identified in the synthesis. These challenges are intensified when future revenues depend on services, customer segments, or ecosystem arrangements whose demand has not yet been established.

The underlying problem is therefore not simply that future networks may be expensive. It is the temporal and strategic asymmetry between relatively certain investment commitments and comparatively uncertain future revenue. Infrastructure, spectrum, computing capacity, integration, and organisational transformation may require expenditure well before adoption levels, willingness to pay, or sustainable revenue streams can be demonstrated. Earlier-generation operational evidence illustrates how high deployment expenditure can coexist with constrained ARPU and limited growth in traditional connectivity revenues, thereby placing pressure on conventional operator models [90], [91].

This finding is especially relevant to the business-model propositions identified elsewhere in the review. Network-as-a-Service, Slice-as-a-Service, shared infrastructure, private networks, data marketplaces, and capability-based services may create new opportunities for value capture, but RQ4 shows that the existence of such opportunities does not resolve the underlying commercial question of who pays, how much, under what conditions, and how revenues and costs are distributed among participating actors.

Monetisation uncertainty is therefore not a secondary issue that follows technological deployment. It is part of the investment problem itself. Where revenue mechanisms remain unclear, projected cash flows become more uncertain, weakening the basis for investment decisions. Similarly, where pricing is technically possible but insufficient demand exists at an acceptable price, the corresponding business model may remain economically unattractive.

This interpretation also helps explain why the RQ4 results repeatedly connect pricing, customer willingness to pay, cost allocation, resource-sharing arrangements, and revenue distribution. A technically differentiated service only becomes commercially sustainable when the resulting value proposition can support an economically acceptable transaction structure for the actors responsible for investment and service provision [92], [93].

7.11.3 Ecosystem expansion creates both opportunity and coordination risk

The prominence of multi-stakeholder coordination and collaboration as the most frequently identified individual barrier is particularly significant. Many of the business configurations associated with future networks rely on broader and more heterogeneous ecosystems than the traditional vertically integrated mobile-operator model.

Infrastructure providers, MNOs, cloud providers, service providers, vertical industries, local operators, application developers, equipment vendors, data providers, satellite operators, and public authorities may all participate in the creation and delivery of a single service. This creates new opportunities for specialisation and shared value creation, but also increases interdependence.

The resulting coordination problem operates at several levels. Actor roles may be unclear, investment responsibilities may be distributed unevenly, and the actor generating a technical capability may not be the actor able to capture the corresponding economic value. Participants may also have conflicting incentives regarding infrastructure sharing, openness, customer ownership, data access, pricing, and long-term investment.

The findings therefore reveal a tension at the centre of platform- and ecosystem-oriented business models. Expanding the number of actors can enlarge the opportunity for specialised value creation while simultaneously increasing the difficulty of organising that value creation into a stable commercial system. Brokerage and platform mechanisms may reduce some direct coordination burdens, but they also create new governance questions concerning pricing, access, market power, risk allocation, and accountability [95].

This issue is likely to become increasingly important in 6G-oriented configurations because several anticipated developments—including local and private networks, non-terrestrial integration, open architectures, distributed computing, AI-enabled services, and capability marketplaces—depend on interaction across organisational and technological boundaries. The commercial challenge is therefore not merely to identify all necessary stakeholders, but to construct a value network in which roles, incentives, responsibilities, and returns remain sufficiently aligned for participation to be sustainable.

7.11.4 Technical openness and service flexibility can introduce new commercial dependencies

The technical barriers identified in RQ4 also reveal an important duality. Many of the architectural characteristics expected to support new business opportunities—softwarisation, openness, virtualisation, disaggregation, orchestration, and multi-domain integration—can themselves generate new implementation and coordination burdens.

Greater modularity and openness may reduce dependence on proprietary end-to-end systems and enable more flexible procurement or service composition. However, these benefits depend on effective interoperability, orchestration, reliability, and management across different vendors, platforms, and organisational domains. Where these requirements are not met, the same architectural openness that enables new business arrangements can increase integration complexity and operating costs [89], [96].

Similarly, virtualised and software-based services may support more configurable commercial propositions, but service failures can acquire direct contractual consequences when technical performance is linked to SLA commitments, compensation, or payment structures [73], [97].

Technical risk therefore becomes commercially relevant not simply because performance is lower, but because performance degradation can affect cost, contractual obligations, customer experience, service scalability, or the credibility of the value proposition.

This is particularly important for 6G, where many proposed business models depend on increasingly complex technical combinations rather than on a single enabling technology. The commercial viability of such configurations is consequently sensitive to the ability to integrate and operate multiple technical components reliably and at acceptable cost.

The findings therefore suggest that future-network business-model design should treat technical architecture and commercial architecture as interdependent but analytically distinct. Technical openness, programmability, and flexibility may enlarge the space of possible business models, but they do not remove the need to demonstrate that the resulting service can be integrated, operated, governed, and delivered economically.

7.11.5 Regulation, organisational capability, and sustainability as conditions of commercial feasibility

The RQ4 findings further show that several barriers commonly treated as external to the business model are in practice closely connected to its feasibility. Regulation, organisational capability, security, privacy, and sustainability can shape both the costs of participation and the set of commercially possible configurations.

Regulatory arrangements are particularly influential for business models that depart from the conventional nationwide MNO structure. Spectrum access, licensing, competition rules, infrastructure-sharing provisions, data governance, and authorisation requirements may determine whether local operators, neutral hosts, private networks, virtual operators, or satellite-integrated services can participate in the market at all. Regulation therefore affects more than compliance expenditure; it can shape market entry, resource access, actor roles, interconnection, and scalability across jurisdictions [103].

Organisational capabilities form a related constraint. Future-network business models may require telecommunications firms to develop skills in software, cloud systems, analytics, AI, platform management, vertical-market engagement, and ecosystem orchestration. These requirements can impose transition costs even where the underlying technology is available. Legacy infrastructure, established organisational structures, and vendor dependencies can further constrain the ability of firms to adopt more open and service-oriented configurations [99], [104].

Security and privacy create similar interactions. Distributed and data-intensive business models may rely on data exchange across multiple organisations, yet the commercial value of such arrangements may be weakened by concerns regarding trust, liability, regulatory compliance, or accountability [99], [100]. In this sense, data access can simultaneously represent a source of potential value and a source of commercial risk.

Sustainability also enters the business-model problem in more than one way. Energy consumption and environmental obligations may increase operating or investment costs, while sustainability objectives may influence customer expectations, stakeholder incentives, and regulatory requirements. The RQ4 evidence therefore supports treating sustainability not solely as a technical performance goal, but as one component of the wider economic and organisational conditions under which a future-network business model can remain viable [58], [101], [102].

7.11.6 5G evidence as an operational antecedent, not a forecast of 6G outcomes

The generational composition of the evidence requires particular care in interpreting these barriers. Much of the primary evidence derives from 5G precursor studies, whereas the direct-6G subset remains comparatively small and prospective. This asymmetry should not be treated as a methodological weakness to be concealed; rather, it is informative about the current development of the research field.

The 5G literature provides comparatively mature evidence concerning deployment cost, investment decisions, demand, ARPU, pricing, organisational transformation, and commercial adoption. These findings identify barriers that have already become visible in the deployment and commercialisation of advanced mobile-network services.

The direct-6G literature, by contrast, more often anticipates challenges associated with emerging governance structures, technology maturity, energy requirements, stakeholder configurations, and regulatory preparedness. The comparatively lower frequency of some established market barriers within direct-6G studies therefore does not demonstrate that those problems will disappear. It more plausibly reflects the fact that many 6G markets, demand structures, and operating models have not yet matured sufficiently for equivalent operational evidence to exist.

Accordingly, 5G evidence provides an important operational antecedent for understanding possible 6G commercialisation constraints, but it should not be interpreted as direct evidence that the same barriers will occur with identical mechanisms or severity in future 6G environments. The transition towards 6G may modify some constraints, intensify others, and introduce new forms of interdependence.

7.11.7 Implications for 6G business-model development

Taken together, RQ4 suggests that successful 6G business-model development will require more than the identification of an attractive archetype, a technically feasible service, or a potential revenue mechanism. Commercial realisation depends on whether those elements can operate within a coherent system of investment incentives, value-capture mechanisms, stakeholder relationships, organisational capabilities, technical service conditions, and regulatory rules.

This has an important implication for future business-model design. Barriers should not be examined only as separate technical, economic, organisational, or regulatory checklists. The evidence indicates that they frequently interact. Interoperability problems may increase costs; higher costs may worsen ROI; weak ROI may increase dependence on shared infrastructure; sharing may require new governance and revenue-allocation arrangements; and those arrangements may depend on spectrum, competition, or data regulation. Removing one constraint may therefore shift pressure elsewhere in the business model rather than resolving the viability problem entirely.

The central challenge identified by RQ4 is consequently one of alignment. A future-network business model becomes more credible when the technical service can be delivered reliably, the investment can be justified, the value can be captured and distributed acceptably, the necessary organisations possess appropriate capabilities, and the institutional environment permits the proposed arrangement to operate.

RQ4 therefore provides the realisation boundary for the opportunities identified elsewhere in the review. New archetypes and technical capabilities expand the space of possible 6G business models, but the commercial significance of those possibilities depends on whether they can be converted into stable, investable, governable, and institutionally feasible configurations. In this sense, the principal obstacle to 6G business-model realisation is not any single technology, economic parameter, or regulation, but the challenge of constructing a coherent commercial ecosystem in which technical performance can be

translated into sustainable value creation and capture across all actors required to deploy, operate, and use the service.

7.12 Direct Answer to RQ4

The reviewed literature identifies barriers to the realisation of proposed 6G business models across all four dimensions specified in RQ4: technical, economic/commercial, organisational/ecosystem, and regulatory/institutional. Economic and commercial barriers were the most prevalent domain, appearing in 83 of the 91 primary studies (91.2%), followed by organisational/ecosystem barriers in 72 studies (79.1%), technical barriers in 69 (75.8%), and regulatory/institutional barriers in 57 (62.6%).

At a higher level of synthesis, the most prevalent challenges concerned investment and economic viability, ecosystem coordination and governance, monetisation and market formation, and technical service realisation. High capital and operating costs, uncertain returns, weak or uncertain demand, unresolved pricing and revenue-sharing arrangements, unclear stakeholder roles, interoperability and orchestration challenges, and regulatory constraints repeatedly affected the feasibility of proposed business configurations. Security, privacy, sustainability, organisational capabilities, and legacy transformation introduced additional cross-cutting constraints.

The findings therefore indicate that the realisation of 6G business models is not constrained by a single dominant obstacle or by technological readiness alone. Instead, business-model viability depends on the alignment of technical service capability with investment sustainability, monetisation logic, ecosystem governance, organisational capabilities, and regulatory feasibility. Technical challenges become commercially significant when they are linked to consequences such as higher cost, contractual or service risk, limited scalability, delayed deployment, or reduced adoption.

The generational comparison further shows that the available 5G evidence provides a more operational basis for understanding deployment cost, investment, demand, pricing, and adoption barriers, whereas direct 6G evidence remains more prospective and places comparatively greater emphasis on emerging governance structures, technological maturity, energy requirements, stakeholder configurations, and regulatory preparedness. Accordingly, 5G evidence should be interpreted as an antecedent informing possible 6G barriers rather than as direct proof that identical commercial outcomes will occur in 6G.

Overall, the literature portrays 6G business-model realisation as a system-level viability challenge in which technical performance must be converted into sustainable value creation and capture across a coordinated and institutionally feasible ecosystem.

7.13 RQ4-Specific Limitations

The interpretation of RQ4 should account for differences in the maturity and provenance of the underlying evidence. The primary synthesis included 91 studies spanning empirical, techno-economic, conceptual, foresight, and secondary forms of evidence. Many direct 6G studies remain prospective, whereas the 5G literature contains a larger body of operational evidence concerning deployment, investment, adoption, and commercial implementation. Barrier prevalence should therefore be interpreted as the distribution of reported evidence within the reviewed corpus rather than as a direct measure of the probability, severity, or future commercial impact of individual barriers.

The multi-label coding framework also means that individual studies could contribute to several barrier domains, canonical categories, and higher-order themes. The reported percentages are consequently

non-mutually exclusive and should not be interpreted as additive shares of a single barrier structure. In addition, the higher-order themes represent an interpretive cross-domain synthesis of the canonical barrier codes rather than a second independent classification system.

A further limitation concerns attribution. Many technical, regulatory, and ecosystem challenges were discussed within complex multi-technology or multi-actor configurations. Only barriers for which the reviewed source supported a sufficiently clear business-model consequence were included in the primary synthesis. This conservative boundary reduces the risk of treating generic 5G or 6G research challenges as commercial barriers, but it may also exclude indirect relationships that could become economically important in practice.

Generational comparisons should likewise be interpreted cautiously because the evidence groups were unequal in size, particularly for B5G transition studies ($n = 7$) and direct 6G studies ($n = 14$). Within-generation percentages were used descriptively, but no inferential statistical comparison was performed. Apparent differences between generations therefore describe the composition of the reviewed evidence rather than statistically established differences in the wider literature.

Finally, evidence derived from 5G and B5G should not be interpreted as direct confirmation that the same barriers will occur with the same magnitude or mechanism in 6G. Earlier-generation evidence was used as an operational antecedent for understanding possible future-network constraints, while direct 6G studies were interpreted according to their more prospective evidential status. The identified barriers therefore represent the challenges currently articulated in the literature rather than deterministic forecasts of future 6G commercial outcomes.

8. Cross-RQ Synthesis: From Business-Model Proposition to Commercial Realisation

The combined findings across RQ1–RQ4 suggest that the development of 6G business models is best understood as a progressive translation process from commercial proposition to realisable market configuration, rather than as the simple emergence of a new set of business-model archetypes associated with a new network generation.

RQ1 showed that much of the emerging 6G business-model landscape is characterised by continuity, recombination, and extension. Several prominent archetypes—including slicing-based services, infrastructure sharing, vertical solutions, capability-based service provision, and data-oriented value capture—have clear antecedents in the 5G literature. At the same time, platform/ecosystem orchestration remains prominent across generations, while sustainability-centred and decentralised marketplace logics appear more strongly concentrated in the forward-looking B5G and 6G evidence. The transition towards 6G therefore appears to involve less wholesale replacement of established commercial structures and more reconfiguration of existing mechanisms within increasingly programmable, heterogeneous, and multi-actor ecosystems [45], [74].

RQ2 extends this finding by showing that the commercial significance of these business-model configurations depends on how underlying technical capabilities are translated into economically meaningful offerings. Technical enablers do not automatically generate revenue simply because they improve network performance, flexibility, coverage, or efficiency. In many cases, their primary contribution is to strengthen the economics or feasibility of a broader business configuration rather than to create an independently monetisable product.

Where direct monetisation does occur, the evidence suggests that an intermediate process of productisation is often required. A technical capability becomes commercially actionable when it can be configured, measured, packaged, allocated, accessed, or exchanged as an identifiable service or resource. This logic is especially visible in Network Slicing, where programmable network resources can be transformed into differentiated service environments and linked to leasing, usage-based charging, resource trading, or SLA-related pricing [64], [65].

The same principle can extend more broadly to capability exposure, infrastructure access, marketplace services, and other modular forms of network provision. The relationship between RQ1 and RQ2 can therefore be expressed as a distinction between business-model structure and commercial mechanism. RQ1 identifies the organisational forms through which value creation and exchange may be arranged, whereas RQ2 identifies how technical capabilities can support the value propositions and value-capture mechanisms required to make those arrangements economically actionable. A platform, Network-as-a-Service model, local-network configuration, or decentralised marketplace is not commercially meaningful solely because the organisational archetype exists; its viability depends on whether the underlying capabilities can be converted into propositions that ecosystem participants are willing and able to exchange.

RQ3 introduces a further layer by demonstrating that the available evidence does not evaluate all stages of this process with equal maturity. The 5G literature contains a stronger operational and techno-economic orientation, with more frequent use of cost models, revenue assumptions, demand analysis, profitability assessment, simulation, and sensitivity analysis. The 6G literature, by contrast, remains more frequently prospective, with greater emphasis on scenario construction, stakeholder relationships,

ecosystem design, value-network configurations, and possible mechanisms of value capture. This broader distinction is consistent with work arguing that the evaluation of future 6G technologies requires lessons from the more mature techno-economic evidence accumulated around 5G [88].

This difference is important because the existence of an articulated business model or monetisation mechanism should not be confused with demonstrated commercial viability. A proposed value-capture mechanism may identify who could pay, what could be exchanged, or how actors could share value without establishing that the corresponding prices, demand levels, cost structures, or investment conditions are commercially sustainable. Similarly, technical demonstration does not by itself validate a business model. Prototype, testbed, analytical, simulation, and business/economic evidence address different questions and therefore represent different dimensions of maturity [75], [105].

The combined implication of RQ2 and RQ3 is that the pathway from technical capability to monetisation must also pass through an evaluation stage. A technically enabled service can be defined and even monetised conceptually before sufficient evidence exists to determine whether its commercial logic is viable under realistic operating conditions. The progression from capability to value proposition and value capture is therefore not complete until the associated cost structure, demand, stakeholder incentives, pricing logic, and technical service conditions have been evaluated at a level appropriate to the maturity of the proposition.

RQ4 identifies the final and most restrictive part of this process: commercial realisation depends on system-level alignment. Even a technically feasible, clearly productised, and economically evaluated proposition may fail to materialise if investment requirements, ecosystem incentives, organisational capabilities, interoperability, regulation, security, privacy, or sustainability conditions prevent the proposed configuration from operating in practice. This multidimensional interpretation is consistent with broader future-network literature emphasising the simultaneous interaction of technological, market, organisational, regulatory, and sustainability conditions in the transition towards 6G [89], [99].

The prevalence of economic/commercial, organisational/ecosystem, technical, and regulatory/institutional barriers demonstrates that these dimensions cannot be treated independently. High infrastructure or integration costs may weaken ROI; uncertain ROI may increase dependence on sharing or partnership arrangements; those arrangements require acceptable governance and revenue allocation; and the feasibility of the resulting ecosystem may depend on spectrum access, competition rules, data governance, or other institutional conditions. Technical architecture and commercial architecture are therefore interdependent even though they should remain analytically distinct.

When the four RQs are considered together, the evidence supports the following integrated pathway:

Business-Model Archetype → Technical Capability → Value Proposition → Productisation → Value-Capture Mechanism → Evaluation and Evidence → Realisation Conditions → Commercial Viability

This pathway should not be interpreted as a strictly linear sequence. Feedback can occur between stages. Economic constraints may influence technical architecture; regulatory conditions may shape which archetypes are feasible; stakeholder incentives may determine whether a capability is productised; and evaluation may lead to redesign of both technical and commercial arrangements. Nevertheless, the sequence provides a useful analytical structure for understanding where proposed 6G business models can fail to progress from conceptual possibility to commercially sustainable implementation.

The cross-RQ findings also suggest that novelty and viability are distinct dimensions. A business model may be conceptually novel but commercially immature, while an inherited 5G mechanism may remain highly relevant if it can be recombined effectively with emerging 6G capabilities. Conversely, a

technically advanced 6G service does not necessarily require a wholly new business-model archetype; its commercial novelty may instead lie in how established mechanisms such as sharing, service provision, platforms, or differentiated access are reorganised across new actors and technical domains.

This distinction helps clarify the broader trajectory of 6G business-model development. The literature does not yet indicate a single dominant 6G business model. Instead, it points towards a portfolio of evolving commercial configurations in which established mechanisms are combined with new forms of capability exposure, platform orchestration, sustainability-oriented value creation, distributed service provision, and multi-actor exchange.

The main challenge is consequently not simply to invent new business-model archetypes. It is to construct configurations in which technical capabilities can be converted into recognisable value propositions, productised into exchangeable services or resources, supported by credible evaluation, and embedded within economic, organisational, technical, and regulatory conditions that allow value to be created and captured sustainably.

The overall synthesis therefore positions 6G business-model development as a problem of commercial translation and ecosystem alignment. Technical innovation expands the space of possible value propositions, but commercial realisation depends on whether those possibilities can be organised into investable, measurable, governable, and institutionally feasible arrangements. In this sense, the progression from 5G to 6G is not simply a technological transition. It is also a transition in how network capabilities are organised, exposed, evaluated, exchanged, and coordinated across increasingly complex value networks.

9. Conclusions and Future Research Directions

9.1 Conclusions

This systematic literature review examined the emerging business-model landscape associated with 5G, B5G, and 6G networks through four complementary research questions addressing business-model archetypes, technical enablers and value capture, evaluation approaches, and barriers to commercial realisation.

The findings indicate that the transition towards 6G is characterised less by the wholesale replacement of existing telecommunications business models and more by their evolution, recombination, and extension. Several prominent archetypes, including slicing-based services, infrastructure sharing, vertical solutions, and capability-based service provision, have clear foundations in the 5G literature. At the same time, platform and ecosystem-oriented configurations remain important across generations, while sustainability-centred and decentralised marketplace models represent more distinctly forward-looking directions.

The review also shows that technical innovation does not automatically translate into commercial value. Technical enablers frequently contribute through improved efficiency, flexibility, performance, coverage, or service differentiation without generating a direct revenue stream. Explicit monetisation becomes clearer when capabilities can be productised into identifiable services or resources that can be accessed, allocated, traded, leased, or otherwise exchanged. Network Slicing provides the clearest example of this process, but the underlying principle extends to broader forms of capability exposure and service-based provision.

The available evidence further demonstrates that commercial propositions are evaluated at different levels of maturity. The 5G literature exhibits a stronger operational and techno-economic orientation, whereas much of the emerging 6G literature remains more prospective and ecosystem-oriented. Technical evidence and business/economic maturity therefore need to remain analytically distinct: demonstrating technical feasibility does not by itself establish that pricing, demand, investment, stakeholder incentives, or value-capture arrangements are commercially viable.

Commercial realisation is further constrained by the interaction of economic, organisational, technical, and regulatory conditions. Investment requirements, monetisation uncertainty, ecosystem coordination, interoperability, organisational capability, regulation, security, privacy, and sustainability do not operate independently. The viability of a proposed business model therefore depends on whether these conditions can be aligned sufficiently to support deployment, operation, participation, and value capture.

Across the four research questions, 6G business-model development can therefore be understood as a process of commercial translation and ecosystem alignment. Technical capabilities must first be translated into recognisable and exchangeable forms of value; the resulting propositions must be supported by evidence appropriate to their level of maturity; and the wider economic, organisational, technical, and institutional environment must permit implementation. These processes are iterative rather than strictly sequential, since commercial constraints may reshape technical design, stakeholder incentives may alter value-capture arrangements, and regulatory conditions may determine which configurations can progress beyond conceptual development.

The principal contribution of this review is therefore not the identification of a single dominant 6G business model. Rather, it lies in connecting business-model forms, technical enablement, commercial evaluation, and realisation constraints within a common analytical perspective. The evidence suggests

that the central challenge for 6G business-model development will be less about inventing entirely new commercial archetypes and more about determining which combinations of technical capabilities, value propositions, ecosystem roles, and value-capture mechanisms can be converted into credible and sustainable market configurations.

As 6G technologies and standards progress towards implementation, research will increasingly need to move from prospective commercial possibilities towards stronger evidence concerning what can be productised, who is willing to pay, how investment and risk are distributed, which actors have sufficient incentives to participate, and whether proposed configurations can operate under realistic market and institutional conditions. The commercial future of 6G will therefore depend not only on what the technology makes possible, but on whether those possibilities can be organised into viable, governable, and sustainable systems of value creation and capture.

9.2 Future Research Directions

The findings of this review identify several directions through which future research could strengthen the empirical and commercial foundations of 6G business-model development.

A first priority concerns the transition from prospective business-model configuration towards stronger empirical and operational evaluation. Much of the direct-6G literature remains focused on scenarios, ecosystem structures, anticipated actor roles, and conceptual mechanisms of value creation and capture. As technologies, standards, and service environments become more specified, future studies could progressively test these propositions using explicit cost structures, demand assumptions, pricing parameters, investment requirements, and sensitivity analysis. Longitudinal studies following business-model propositions from experimentation through deployment would be particularly valuable because they could reveal how assumptions concerning demand, costs, partnerships, and value capture change as technologies move closer to commercial implementation. Recent empirical work on 5G commercialisation similarly shows that business-model configurations remain subject to strategic ambiguity during early market formation and explicitly points towards longitudinal and comparative research as a means of examining how such configurations evolve over time [106].

A second direction concerns the stronger integration of technical and business/economic evaluation while preserving their analytical distinction. The review showed that technical feasibility, technical evidence, and business/economic maturity do not necessarily progress together. Future studies could therefore develop evaluation designs that connect technical performance measures with their commercial consequences without treating one as a substitute for the other. For example, latency, reliability, resource utilisation, interoperability, or energy consumption could be linked explicitly to service-level commitments, operating costs, pricing structures, customer value, or investment outcomes.

Earlier 5G work provides useful methodological antecedents for such integrated evaluation. Ben-Ameur et al. jointly model admission control, resource allocation, stochastic demand, QoS requirements, pricing, and stakeholder profit within the same network-slicing framework [107]. Sacoto-Cabrera et al. similarly combine a technical representation of shared network capacity with user utility, subscription behaviour, operator pricing, revenues, and inter-operator incentives in order to assess the conditions under which alternative virtual-operator business models are economically feasible [108].

These examples suggest a useful direction for 6G research: technical and economic parameters could increasingly be evaluated within connected models while the distinct evidential meaning of technical feasibility and commercial viability remains explicit.

A third research priority is the productisation of technical capabilities. The RQ2 findings indicate that direct monetisation becomes clearer when technical resources can be transformed into identifiable commercial objects, such as access rights, allocated network resources, differentiated service levels, or tradable capabilities. Future research could therefore investigate systematically which emerging 6G capabilities can be packaged, measured, contracted, and exchanged, and which are more likely to contribute indirectly through cost reduction, flexibility, automation, or service enhancement.

Operational slicing research provides a useful precursor for examining this process. Borcoci et al. distinguish infrastructure, slice-provider, tenant, and end-user roles and describe arrangements in which virtual resources and network slices can be leased and configured for different service requirements, while also emphasising the increasing complexity of multi-tenant, multi-domain, and multi-operator environments [109]. Future 6G studies could extend this logic to capability-as-a-Service, AI-enabled network functions, distributed computing resources, NTN capabilities, sensing resources, and marketplace-based service exchange, examining not only what can technically be exposed but also how such capabilities become contractible and economically meaningful products.

A fourth direction concerns multi-actor governance and incentive alignment. The combined RQ1 and RQ4 findings suggest that many future business models will depend on increasingly heterogeneous value networks involving operators, infrastructure providers, cloud and edge providers, vertical industries, local-network actors, satellite operators, data providers, platform intermediaries, and public authorities. Future studies should move beyond identifying stakeholder roles towards modelling how investment obligations, costs, risks, revenues, decision rights, and responsibilities are distributed among these actors.

Applied evidence illustrates why this is important. Nesse et al. develop a collaborative 5G/IoT business-model approach in which stakeholder needs, technical solution trials, socioeconomic impact assessment, ecosystem roles, and the distribution of costs and revenues are considered as connected parts of an iterative development process [110]. Importantly, the study is still developmental rather than evidence of a fully validated commercial model, with further large-scale trials and updated business models envisaged. This kind of iterative technical–commercial experimentation provides a useful model for future 6G research in which stakeholder incentives can be reassessed as technical propositions become more mature.

Comparative evaluation of alternative governance arrangements, revenue-sharing mechanisms, brokerage structures, and partnership models would also be valuable. Infrastructure-sharing research demonstrates that commercial viability depends on the interaction between deployment architecture, demand, investment incentives, stakeholder structure, and regulatory conditions rather than on cost reduction alone [111].

A fifth direction is the earlier incorporation of regulatory, organisational, security, privacy, and sustainability conditions into business-model evaluation. These factors should not be treated only as external constraints assessed after a technical or commercial concept has already been designed. Future research could examine how spectrum rules, licensing, competition policy, data governance, organisational capabilities, interoperability requirements, cybersecurity obligations, and energy constraints alter the feasible design space of a business model from the outset. This is particularly important because infrastructure-sharing arrangements already illustrate how technical architecture, investment incentives, market competition, spectrum policy, regulators, operators, and end users can become interdependent within the same commercial configuration [111].

A further opportunity lies in distinguishing more carefully between business-model novelty and business-model recombination. The RQ1 findings suggest that 6G innovation may often emerge through new combinations of established mechanisms rather than through entirely new archetypes. Future research could therefore examine systematically how inherited models such as slicing, infrastructure sharing, vertical service provision, and data monetisation are transformed when combined with platformisation, distributed capability exposure, AI-enabled orchestration, sustainability objectives, or decentralised exchange mechanisms.

This question is particularly relevant because empirical 5G evidence already shows that commercialisation may involve alternative combinations of connectivity provision, Servitisation, vertical specialisation, ecosystem orchestration, and value-appropriation mechanisms rather than a single dominant business-model trajectory [106]. Future research should therefore examine not only whether a 6G business model appears novel, but which components are inherited, which are reconfigured, and where the substantive source of commercial novelty actually resides.

Finally, future research would benefit from comparative and longitudinal evidence across generations, markets, and deployment contexts. The current literature contains substantially more operational evidence for 5G than for direct 6G, and earlier-generation findings should therefore remain an antecedent rather than a deterministic forecast of 6G outcomes. Comparative studies across countries, regulatory regimes, urban and rural environments, public and private deployments, and different ecosystem structures could identify which commercial mechanisms are transferable and which are context dependent. Existing infrastructure-sharing evidence already demonstrates substantial sensitivity of business viability to deployment context, demand conditions, sharing structure, and policy environment [111].

As real-world 6G experimentation environments emerge, the most valuable progression will be from conceptual propositions towards evidence that jointly examines technical operation, economic viability, stakeholder participation, customer adoption, and institutional feasibility. Iterative approaches combining technical trials with stakeholder impact assessment and subsequent business-model revision provide one possible path towards this stronger evidence base [110].

Overall, future 6G business-model research should move progressively from identifying possible commercial configurations towards testing the conditions under which those configurations can become sustainable in practice. This requires stronger evidence not only about what technologies can enable, but also about what can be productised, who is willing to pay, how value and risk are distributed, which actors have incentives to participate, and whether the resulting arrangement can operate within realistic technical, organisational, economic, and regulatory conditions.

References

- [1] X. You *et al.*, “Towards 6G wireless communication networks: vision, enabling technologies, and new paradigm shifts,” *Sci. China Inf. Sci.*, vol. 64, no. 1, p. 110301, Jan. 2021, doi: 10.1007/s11432-020-2955-6.
- [2] V. Ziegler and S. Yrjola, “6G Indicators of Value and Performance,” in *2020 2nd 6G Wireless Summit (6G SUMMIT)*, Levi, Finland: IEEE, Mar. 2020, pp. 1–5. doi: 10.1109/6GSUMMIT49458.2020.9083885.
- [3] Nidhi, A. Mihovska, A. Kumar, and R. Prasad, “Business Opportunities for Beyond 5G and 6G Networks,” in *2022 25th International Symposium on Wireless Personal Multimedia Communications (WPMC)*, Herning, Denmark: IEEE, Oct. 2022, pp. 543–548. doi: 10.1109/WPMC55625.2022.10014752.
- [4] W. Lehr, F. Queder, and J. Haucap, “5G: A new future for Mobile Network Operators, or not?,” *Telecommunications Policy*, vol. 45, no. 3, p. 102086, Apr. 2021, doi: 10.1016/j.telpol.2020.102086.
- [5] S. Yrjola, “Technology Antecedents of the Platform-Based Ecosystemic Business Models beyond 5G,” in *2020 IEEE Wireless Communications and Networking Conference Workshops (WCNCW)*, Seoul, Korea (South): IEEE, Apr. 2020, pp. 1–8. doi: 10.1109/WCNCW48565.2020.9124823.
- [6] E. Meraviglia, M. Magnaghi, A. Capone, N. B. Melazzi, M. Valsecchi, and L. Dozio, “A Techno-Economic View of the Future of Telecommunications,” in *2025 23rd Mediterranean Communication and Computer Networking Conference (MedComNet)*, Cagliari, Italy: IEEE, Jun. 2025, pp. 1–6. doi: 10.1109/MedComNet65822.2025.11103520.
- [7] M. F. G. Trischler and J. Li-Ying, “Digital business model innovation: toward construct clarity and future research directions,” *Rev Manag Sci*, vol. 17, no. 1, pp. 3–32, Jan. 2023, doi: 10.1007/s11846-021-00508-2.
- [8] H.-S. Jang and J. Yeo, “Current status analysis of 5G mobile communication services industry using business model canvas in South Korea,” *Asia Pacific Management Review*, vol. 29, no. 4, pp. 462–476, Dec. 2024, doi: 10.1016/j.apmr.2024.11.002.
- [9] G. Darzanos, C. Kalogiros, G. D. Stamoulis, H. K. Hallingby, and Z. Frias, “An Open Framework for the Assessment of 5G Business Cases and Investments,” *IEEE Commun. Mag.*, vol. 61, no. 2, pp. 44–50, Feb. 2023, doi: 10.1109/MCOM.001.2200304.
- [10] M. Magnaghi, A. Ghezzi, and A. Rangone, “5G is not just another G: A review of the 5G business model and ecosystem challenges,” *Technological Forecasting and Social Change*, vol. 215, p. 124121, Jun. 2025, doi: 10.1016/j.techfore.2025.124121.
- [11] H. Kim, *Artificial Intelligence for 6G*. Cham: Springer International Publishing, 2022. doi: 10.1007/978-3-030-95041-5.
- [12] W. Guan and H. Zhang, *Network Slicing for Future Wireless Communication: Theory and Application*. in Wireless Networks. Cham: Springer Nature Switzerland, 2024. doi: 10.1007/978-3-031-58229-5.
- [13] M. Quagliotti, L. Serra, A. Pagano, P. Groumas, P. Bakopoulos, and H. Avramopoulos, “Disaggregation and cloudification of metropolitan area networks: enabling technologies and impact on architecture, cost, and power consumption [Invited],” *J. Opt. Commun. Netw.*, vol. 14, no. 6, p. C38, Jun. 2022, doi: 10.1364/JOCN.450822.
- [14] I. Al-Surmi, B. Raddwan, and I. Al-Baltah, “Next Generation Mobile Core Resource Orchestration: Comprehensive Survey, Challenges and Perspectives,” *Wireless Pers Commun*, vol. 120, no. 2, pp. 1341–1415, Sep. 2021, doi: 10.1007/s11277-021-08517-w.
- [15] A. Jahid, M. H. Alsharif, and T. J. Hall, “The convergence of blockchain, IoT and 6G: Potential, opportunities, challenges and research roadmap,” *Journal of Network and Computer Applications*, vol. 217, p. 103677, Aug. 2023, doi: 10.1016/j.jnca.2023.103677.
- [16] H. Taherdoost, “A comparative analysis of 6G and 5G technologies for metaverse connectivity dynamics,” *Discov Netw*, vol. 2, no. 1, p. 2, Feb. 2026, doi: 10.1007/s44354-026-00017-2.
- [17] L. M. Contreras, S. Barguil, R. Vilalta, and V. López, “Architecture for integrating vertical customer’s programmability control of network functions and connectivity in a slice-as-a-service

- schema,” *J Wireless Com Network*, vol. 2021, no. 1, p. 114, Dec. 2021, doi: 10.1186/s13638-021-01992-6.
- [18] O. Kolosov, G. Yadgar, D. Breitgand, and D. H. Lorenz, “PASE: Pro-active Service Embedding in The Mobile Edge,” *J Netw Syst Manage*, vol. 33, no. 1, p. 3, Jan. 2025, doi: 10.1007/s10922-024-09877-x.
- [19] P. Hanafizadeh, P. Hatami, M. Analoui, and A. Albadvi, “Business model innovation driven by the internet of things technology, in internet service providers’ business context,” *Inf Syst E-Bus Manage*, vol. 19, no. 4, pp. 1175–1243, Dec. 2021, doi: 10.1007/s10257-021-00537-0.
- [20] A. F. Barciela, M. Dillinger, J. Alonso-Zarate, A. Laya, P. Lindberg, and K. Manolakis, “Business Models,” in *Cellular V2X for Connected Automated Driving*, 1st ed., M. Fallgren, M. Dillinger, T. Mahmoodi, and T. Svensson, Eds., Wiley, 2021, pp. 21–61. doi: 10.1002/9781119692676.ch2.
- [21] D. Cagáňová and N. Hornáková, Eds., *Industry 4.0 Challenges in Smart Cities*. in EAI/Springer Innovations in Communication and Computing. Cham: Springer International Publishing, 2023. doi: 10.1007/978-3-030-92968-8.
- [22] C. Bagnoli *et al.*, *Digital Business Models for Industry 4.0: How Innovation and Technology Shape the Future of Companies*. in Future of Business and Finance. Cham: Springer International Publishing, 2022. doi: 10.1007/978-3-030-97284-4.
- [23] H. Øverby and J. A. Audestad, *Introduction to Digital Economics: Foundations, Business Models and Case Studies*. in Classroom Companion: Business. Cham: Springer International Publishing, 2021. doi: 10.1007/978-3-030-78237-5.
- [24] R. Henríquez, F. X. Martínez De Osés, and J. E. Martínez Marín, “Technological drivers of seaports’ business model innovation: An exploratory case study on the port of Barcelona,” *Research in Transportation Business & Management*, vol. 43, p. 100803, Jun. 2022, doi: 10.1016/j.rtbm.2022.100803.
- [25] M. Kohtamäki *et al.*, Eds., *The Palgrave Handbook of Servitization*. Cham: Springer International Publishing, 2021. doi: 10.1007/978-3-030-75771-7.
- [26] S. Kurpiela and F. Teuteberg, “Product-service system-oriented business models: a taxonomy of startups in the mobility sector,” *Inf Syst E-Bus Manage*, vol. 21, no. 4, pp. 837–861, Dec. 2023, doi: 10.1007/s10257-023-00649-9.
- [27] M. Kim, “Connecting artificial intelligence to value creation in services: mechanism and implications,” *Serv Bus*, vol. 17, no. 4, pp. 851–878, Dec. 2023, doi: 10.1007/s11628-023-00547-7.
- [28] D. Petrik, A. Saltan, and A. Helferich, Eds., *Digital Product Management in the Era of Data Economy, Artificial Intelligence, and Ecosystems: First International Conference on Digital Product Management, ICDPM 2024, Gothenburg, Sweden, June 12, 2024, Proceedings*, vol. 528. in Lecture Notes in Business Information Processing, vol. 528. Cham: Springer Nature Switzerland, 2025. doi: 10.1007/978-3-031-71515-0.
- [29] L. S. Da-Silva, C. R. Storck, I. F. D. Alvarenga, T. A. Alves, and F. D. L. P. Duarte-Figueiredo, “Local 5G and 6G micro-operators for new business models: a systematic literature review,” *OLEL*, vol. 23, no. 2, p. e9023, Feb. 2025, doi: 10.55905/oelv23n2-088.
- [30] Z. Zhang, Y. Kang, Y. Lu, and P. Li, “The Role of Artificial Intelligence in Business Model Innovation of Digital Platform Enterprises,” *Systems*, vol. 13, no. 7, p. 507, Jun. 2025, doi: 10.3390/systems13070507.
- [31] C. E. Palau *et al.*, Eds., *Interoperability of Heterogeneous IoT Platforms: A Layered Approach*. in Internet of Things. Cham: Springer International Publishing, 2021. doi: 10.1007/978-3-030-82446-4.
- [32] C. Canova, F. Pacella, D. Brevi, M. Apruzzese, and R. Cavicchioli, “Driving Safety & Awareness Cooperative Business Model exploiting the 5GMETA platform,” in *2022 IEEE Future Networks World Forum (FNWF)*, Montreal, QC, Canada: IEEE, Oct. 2022, pp. 299–304. doi: 10.1109/FNWF55208.2022.00059.
- [33] F. Sterk, A. Stocker, D. Heinz, and C. Weinhardt, “Unlocking the value from car data: A taxonomy and archetypes of connected car business models,” *Electron Markets*, vol. 34, no. 1, p. 13, Dec. 2024, doi: 10.1007/s12525-024-00692-5.
- [34] X.-S. Yang, S. Sherratt, N. Dey, and A. Joshi, Eds., *Proceedings of Ninth International Congress on Information and Communication Technology: ICICT 2024, London, Volume 6*, vol. 1002. in

- Lecture Notes in Networks and Systems, vol. 1002. Singapore: Springer Nature Singapore, 2024. doi: 10.1007/978-981-97-3299-9.
- [35] V. S. C. Tunn, E. A. Van Den Hende, N. M. P. Bocken, and J. P. L. Schoormans, “Digitalised product-service systems: Effects on consumers’ attitudes and experiences,” *Resources, Conservation and Recycling*, vol. 162, p. 105045, Nov. 2020, doi: 10.1016/j.resconrec.2020.105045.
- [36] A. Chiha, F. Vannieuwenborg, B. Denis, D. Colle, and S. Verbrugge, “Cooperative, Connected and automated mobility (CCAM) services provisioning in cross-border settings: Techno-economic analysis in the light of technical challenges,” *Transport Policy*, vol. 140, pp. 68–84, Sep. 2023, doi: 10.1016/j.tranpol.2023.06.005.
- [37] C. J. Bouras and A. Kollia, “Analyzing mmWave Bands From a Techno-Economic Perspective in 5G Networks;,” *International Journal of Business Data Communications and Networking*, vol. 19, no. 1, pp. 1–20, Nov. 2024, doi: 10.4018/IJBDCN.361890.
- [38] J. Fontalvo-Hernández, R. Romero-Reyes, and A. Zirkler, “A Techno-Economic Method for Evaluating 5G-TSN/DetNet Designs in Industry 4.0,” in *2025 IEEE Latin-American Conference on Communications (LATINCOM)*, Antigua, Guatemala: IEEE, Nov. 2025, pp. 1–8. doi: 10.1109/LATINCOM67778.2025.11345426.
- [39] V. Sanchez-Aguero *et al.*, “Deploying an NFV-Based Experimentation Scenario for 5G Solutions in Underserved Areas,” *Sensors*, vol. 21, no. 5, p. 1897, Mar. 2021, doi: 10.3390/s21051897.
- [40] A. M. Cavalcante, M. V. Marquezini, L. Mendes, and C. S. Moreno, “5G for Remote Areas: Challenges, Opportunities and Business Modeling for Brazil,” *IEEE Access*, vol. 9, pp. 10829–10843, 2021, doi: 10.1109/ACCESS.2021.3050742.
- [41] A. L. Martins, J. C. Ferreira, A. Kocian, U. Tokkozhina, B. I. Helgheim, and S. Bråthen, Eds., *Intelligent Transport Systems: 7th EAI International Conference, INTSYS 2023, Molde, Norway, September 6-7, 2023, Proceedings*, vol. 540. in Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, vol. 540. Cham: Springer Nature Switzerland, 2024. doi: 10.1007/978-3-031-49379-9.
- [42] E. C. Blessie, B. Sundaravadivazhagan, and V. Kumutha, “Logistic industrial digital transformation with 6G – a study on the technological innovations, process, impact, and future challenges,” in *Advances in Computers*, vol. 139, Elsevier, 2025, pp. 177–201. doi: 10.1016/bs.adcom.2025.03.026.
- [43] C. Suraci, G. Araniti, A. Abrardo, G. Bianchi, and A. Iera, “A stakeholder-oriented security analysis in virtualized 5G cellular networks,” *Computer Networks*, vol. 184, p. 107604, Jan. 2021, doi: 10.1016/j.comnet.2020.107604.
- [44] O. Gisca, M. Matinmikko-Blue, P. Ahokangas, S. Yrjölä, and J. Gordon, “Regulatory challenges and implications of the European electronic communications code (EECC) for local mobile communication network business,” *Telecommunications Policy*, vol. 47, no. 10, p. 102651, Nov. 2023, doi: 10.1016/j.telpol.2023.102651.
- [45] S. Yrjölä, P. Ahokangas, and M. Matinmikko-Blue, “Value Creation and Capture From Technology Innovation in the 6G Era,” *IEEE Access*, vol. 10, pp. 16299–16319, 2022, doi: 10.1109/ACCESS.2022.3149590.
- [46] P. L. Mehta, A. Kumar, B. Mohammad, and R. Prasad, “A Technological and Business Perspective on Connected Drones for 6G and Beyond Mobile Wireless Communications,” *Wireless Pers Commun*, vol. 127, no. 3, pp. 2605–2624, Dec. 2022, doi: 10.1007/s11277-022-09887-5.
- [47] L. Banda, M. Mzyece, and F. Mekuria, “Business Models for 5G and Future Mobile Network Operators,” in *2022 IEEE Future Networks World Forum (FNWF)*, Montreal, QC, Canada: IEEE, Oct. 2022, pp. 215–219. doi: 10.1109/FNWF55208.2022.00045.
- [48] S. Ben Saad, A. Ksentini, and B. Brik, “An end-to-end trusted architecture for network slicing in 5G and beyond networks,” *Security and Privacy*, vol. 5, no. 1, p. e186, Jan. 2022, doi: 10.1002/spy2.186.
- [49] Y. M. Allawi, A. F. Y. Mohammed, E. M. Moneer, M. Shbat, A. Abadleh, and M. Bilal, “Cost-Efficient Citywide Neutral Host Design: A Micro-Operator Business Model for Expedited 5G and Beyond Network Infrastructure Rollout,” *IEICE Trans. Commun.*, vol. E108-B, no. 4, pp. 450–464, Apr. 2025, doi: 10.23919/transcom.2024EBP3099.

- [50] O. Gisca, M. Matinmikko-Blue, P. Ahokangas, J. Gordon, and S. Yrjölä, “Legitimacy considerations in regulation for local mobile communication network business in Finland and the UK,” *Telecommunications Policy*, vol. 48, no. 9, p. 102847, Oct. 2024, doi: 10.1016/j.telpol.2024.102847.
- [51] T. Savunen, P. Kekolahti, P. Mähönen, H. Hämmäinen, and K. Kilkki, “Mobile network operators’ business risks in next-generation public safety services,” *Telecommunications Policy*, vol. 48, no. 4, p. 102733, May 2024, doi: 10.1016/j.telpol.2024.102733.
- [52] T. Savunen, J. Töyli, P. Kekolahti, and P. Mähönen, “Factors driving mobile network operator profitability in public safety mobile broadband projects,” *Telecommunications Policy*, vol. 49, no. 7, p. 102995, Aug. 2025, doi: 10.1016/j.telpol.2025.102995.
- [53] S. K. Rao, “Data-driven Business Model Innovation for 6G,” *JICTS*, Dec. 2021, doi: 10.13052/jicts2245-800X.935.
- [54] M. Apruzzese, N. S. Hadjimitsiou, E. Pautasso, and M. Falbo, “Connecting Data Providers with Data Consumers: the 5GMETA Data Monetisation Framework,” in *2023 IEEE 47th Annual Computers, Software, and Applications Conference (COMPSAC)*, Torino, Italy: IEEE, Jun. 2023, pp. 1896–1901. doi: 10.1109/COMPSAC57700.2023.10260231.
- [55] J. Kim *et al.*, “5G-ALLSTAR: An Integrated Satellite-Cellular System for 5G and Beyond,” in *2020 IEEE Wireless Communications and Networking Conference Workshops (WCNCW)*, Seoul, Korea (South): IEEE, Apr. 2020, pp. 1–6. doi: 10.1109/WCNCW48565.2020.9124751.
- [56] A. Chiha, M. Van Der Wee, L. Goratti, and D. Colle, “Techno-economic analysis of inflight connectivity using an integrated satellite-5G network,” *Satell Commun Network*, vol. 39, no. 4, pp. 322–338, Jul. 2021, doi: 10.1002/sat.1386.
- [57] S. Yrjölä, P. Ahokangas, and M. Matinmikko-Blue, “Sustainability as a Challenge and Driver for Novel Ecosystemic 6G Business Scenarios,” *Sustainability*, vol. 12, no. 21, p. 8951, Oct. 2020, doi: 10.3390/su12218951.
- [58] L. Banda, M. Mzyece, and F. Mekuria, “Green Mobile Operator Business Model for 5G and Beyond Networks,” in *2024 IEEE Future Networks World Forum (FNWF)*, Dubai, United Arab Emirates: IEEE, Oct. 2024, pp. 51–56. doi: 10.1109/FNWF63303.2024.11028748.
- [59] S. Yrjölä, “How Could Blockchain Transform 6G towards Open Ecosystemic Business Models?,” in *2020 IEEE International Conference on Communications Workshops (ICC Workshops)*, Dublin, Ireland: IEEE, Jun. 2020, pp. 1–6. doi: 10.1109/ICCWorkshops49005.2020.9145223.
- [60] L. Jagadeesan, I. Malanchini, P. Naik, and S. Papillon, “Trustworthy Intent-based 6G Services Marketplaces: A Decentralized Finance Perspective,” in *2025 7th International Conference on Blockchain Computing and Applications (BCCA)*, Durbovnic, Croatia: IEEE, Oct. 2025, pp. 702–707. doi: 10.1109/BCCA66705.2025.11229584.
- [61] F. Tobias, “Business Model Innovation Based on Software Robotics for Mobile Network Operators,” Doctor of Business Administration, University of South Wales, 2021.
- [62] Y. Hadjadj-Aoul, M. L. Treust, P. Maillé, and B. Tuffin, “An Economic Analysis of 5G Network Slicing and the Impact of Regulation,” in *2023 31st International Symposium on Modeling, Analysis, and Simulation of Computer and Telecommunication Systems (MASCOTS)*, Stony Brook, NY, USA: IEEE, Oct. 2023, pp. 1–8. doi: 10.1109/MASCOTS59514.2023.10387649.
- [63] S. Wang, J. Qin, X. Qi, Z. Yan, M. He, and Y. Liu, “Discussion on 5G Business Model in Power Industry,” in *2022 IEEE 5th International Electrical and Energy Conference (CIEEC)*, Nanjing, China: IEEE, May 2022, pp. 2872–2875. doi: 10.1109/CIEEC54735.2022.9846465.
- [64] A. L. B. Rocha *et al.*, “CNS-AOM: Design, Implementation and Integration of an Architecture for Orchestration and Management of Cloud-Network Slices,” *J Netw Syst Manage*, vol. 30, no. 2, p. 34, Apr. 2022, doi: 10.1007/s10922-022-09641-z.
- [65] G. Sun, G. O. Boateng, L. Luo, H. Chen, D. A. Mensah, and G. Liu, “Competitive Pricing for Resource Trading in Sliced Mobile Networks: A Multi-Agent Reinforcement Learning Approach,” *IEEE Trans. on Mobile Comput.*, vol. 23, no. 5, pp. 3830–3845, May 2024, doi: 10.1109/TMC.2023.3281203.
- [66] J. Rech, D. D. S. Vasconcelos, and X. L. Travassos, “Cost–Benefit Assessment of 5G Rollout: Insights from Brazil,” *Telecom*, vol. 6, no. 3, p. 44, Jun. 2025, doi: 10.3390/telecom6030044.
- [67] L. Banda, M. Mzyece, and F. Mekuria, “5G Business Models for Mobile Network Operators—A Survey,” *IEEE Access*, vol. 10, pp. 94851–94886, 2022, doi: 10.1109/ACCESS.2022.3205011.

- [68] W. Mao *et al.*, “Multi-Agent Reinforcement Learning-Based Capacity Planning for On-Demand Vehicular Fog Computing,” *IEEE Trans. Intell. Veh.*, vol. 10, no. 2, pp. 1043–1057, Feb. 2025, doi: 10.1109/TIV.2024.3422375.
- [69] C. Bouras, S. Kokkalis, A. Kollia, and A. Papazois, “Techno-economic comparison of MIMO and DAS cost models in 5G networks,” *Wireless Netw.*, vol. 26, no. 1, pp. 1–15, Jan. 2020, doi: 10.1007/s11276-018-1780-6.
- [70] J. Zhao, J. Chen, B. Cheng, B. Qian, Y. Xu, and H. Zhou, “Cost-Effective Deployment for Fully-Decoupled RAN: A Techno-Economic Approach,” *IEEE Trans. Veh. Technol.*, vol. 73, no. 11, pp. 17007–17023, Nov. 2024, doi: 10.1109/TVT.2024.3424547.
- [71] S. V. Pendem, C. Natalino, A. Napoli, and P. Monti, “Hybrid FSO-THz Technologies for 6G Access Networks: A Cost-Availability Trade-off Analysis,” in *2025 25th Anniversary International Conference on Transparent Optical Networks (ICTON)*, Barcelona, Spain: IEEE, Jul. 2025, pp. 1–5. doi: 10.1109/ICTON67126.2025.11125338.
- [72] L. Toka, M. Konrad, A. Pekar, and G. Biczók, “Integrating the Skies for 6G: Techno-Economic Considerations of LEO, HAPS, and UAV Technologies,” *IEEE Commun. Mag.*, vol. 62, no. 11, pp. 44–51, Nov. 2024, doi: 10.1109/MCOM.003.2400120.
- [73] H. Cao, Z. Lin, L. Yang, J. Wang, and M. Guizani, “DT-SFC-6G: Digital Twins Assisted Service Function Chains in Softwarized 6G Networks for Emerging V2 X,” *IEEE Network*, vol. 37, no. 4, pp. 289–296, Jul. 2023, doi: 10.1109/MNET.009.2300028.
- [74] M. Moussaoui, E. Bertin, and N. Crespi, “Divide and Conquer: A Business Model Agenda for Beyond-5G and 6G,” *IEEE Commun. Mag.*, vol. 61, no. 7, pp. 82–88, Jul. 2023, doi: 10.1109/MCOM.001.2200748.
- [75] G. Darzanos, C. Kalogiros, G. D. Stamoulis, H. K. Hallingby, and Z. Frias, “Business Models for 5G Experimentation as a Service: 5G Testbeds and Beyond,” in *2022 25th Conference on Innovation in Clouds, Internet and Networks (ICIN)*, Paris, France: IEEE, Mar. 2022, pp. 169–174. doi: 10.1109/ICIN53892.2022.9758131.
- [76] A. A. Kharlan, Sh. N. Biktimirov, and A. B. Ivanov, “Prospects for the Development of Global Satellite Communication Constellations in the Context of New Services in the Telecommunications Market,” *Cosmic Res.*, vol. 58, no. 5, pp. 402–410, Sep. 2020, doi: 10.1134/S0010952520050044.
- [77] M. Klymash, A. Luntovskyy, M. Beshley, I. Melnyk, and A. Schill, Eds., *Emerging Networking in the Digital Transformation Age: Approaches, Protocols, Platforms, Best Practices, and Energy Efficiency*, vol. 965. in *Lecture Notes in Electrical Engineering*, vol. 965. Cham: Springer Nature Switzerland, 2023. doi: 10.1007/978-3-031-24963-1.
- [78] G. Bugár *et al.*, “Techno-economic framework for dynamic operator selection in a multi-tier heterogeneous network,” *Ad Hoc Networks*, vol. 97, p. 102007, Feb. 2020, doi: 10.1016/j.adhoc.2019.102007.
- [79] T. Kyoseva, V. Poulkov, and P. Lindgren, “The Disruptive Innovation Potential and Business Case Investment Sensitivity of Open RAN,” *JMM*, May 2023, doi: 10.13052/jmm1550-4646.1943.
- [80] L. Song, M. Chen, and Z. Xu, *5GtoB From Theory to Practice*. Singapore: Springer Nature Singapore, 2025. doi: 10.1007/978-981-97-8453-0.
- [81] S. Moqaddamerad and E. Tapinos, “Managing business model innovation uncertainties in 5G technology: a future-oriented sensemaking perspective,” *R & D Management*, vol. 53, no. 2, pp. 244–259, Mar. 2023, doi: 10.1111/radm.12559.
- [82] N. Ye, C. Hou, Q. Ouyang, B. Kang, H. Shin, and S. Mumtaz, “Techno-Economic Assessment of LEO Mega-Constellation with Multi-Satellite Collaboration,” *IEEE Commun. Mag.*, vol. 62, no. 11, pp. 36–42, Nov. 2024, doi: 10.1109/MCOM.006.2400126.
- [83] H. Shin *et al.*, “The future service scenarios of 6G telecommunications technology,” *Telecommunications Policy*, vol. 48, no. 2, p. 102678, Mar. 2024, doi: 10.1016/j.telpol.2023.102678.
- [84] J. R. Bhat and S. A. Alqahtani, “6G Ecosystem: Current Status and Future Perspective,” *IEEE Access*, vol. 9, pp. 43134–43167, 2021, doi: 10.1109/ACCESS.2021.3054833.
- [85] A. Basaure, S. Yrjölä, M. Matinmikko-Blue, P. Ahokangas, and R. Jurva, “Value Network Configurations for Local 6G Deployments,” in *2024 Joint European Conference on Networks and*

- Communications & 6G Summit (EuCNC/6G Summit)*, Antwerp, Belgium: IEEE, Jun. 2024, pp. 1073–1078. doi: 10.1109/EuCNC/6GSummit60053.2024.10597027.
- [86] S. Koratagere Anantha Kumar, R. W. Stewart, D. Crawford, and S. Chaudhari, “Techno-Economic Study of 5G Network Slicing to Improve Rural Connectivity in India,” *IEEE Open J. Commun. Soc.*, vol. 2, pp. 2645–2659, 2021, doi: 10.1109/OJCOMS.2021.3131370.
- [87] H. Frank, C. Colman-Meixner, K. D. R. Assis, S. Yan, and D. Simeonidou, “Techno-Economic Analysis of 5G Non-Public Network Architectures,” *IEEE Access*, vol. 10, pp. 70204–70218, 2022, doi: 10.1109/ACCESS.2022.3187727.
- [88] E. J. Oughton and W. Lehr, “Surveying 5G Techno-Economic Research to Inform the Evaluation of 6G Wireless Technologies,” *IEEE Access*, vol. 10, pp. 25237–25257, 2022, doi: 10.1109/ACCESS.2022.3153046.
- [89] G. E. Corazza *et al.*, “A glimpse on the futures of telecommunication networks: From market, technology and regulation trends to strategic foresight,” *Journal of Open Innovation: Technology, Market, and Complexity*, vol. 12, no. 1, p. 100735, Mar. 2026, doi: 10.1016/j.joitmc.2026.100735.
- [90] G. Otlyvanska, J. Dooley, N. Connolly, and G. Walsh, “Prospects of the neutral host business model for 5G ubiquity coverage in Ireland,” in *2023 31st Telecommunications Forum (TELFOR)*, Belgrade, Serbia: IEEE, Nov. 2023, pp. 1–4. doi: 10.1109/TELFOR59449.2023.10372601.
- [91] E. J. Oughton and A. Jha, “Supportive 5G Infrastructure Policies are Essential for Universal 6G: Assessment Using an Open-Source Techno-Economic Simulation Model Utilizing Remote Sensing,” *IEEE Access*, vol. 9, pp. 101924–101945, 2021, doi: 10.1109/ACCESS.2021.3097627.
- [92] E. Sacoto Cabrera, L. Guijarro, and P. Maillé, “Game Theoretical Analysis of a Multi-MNO MVNO Business Model in 5G Networks,” *Electronics*, vol. 9, no. 6, p. 933, Jun. 2020, doi: 10.3390/electronics9060933.
- [93] E. Moreno-Cardenas and L. Guijarro, “Market and Sharing Alternatives for the Provision of Massive Machine-Type and Ultra-Reliable Low-Latency Communications Services over a 5G Network,” *Electronics*, vol. 12, no. 24, p. 4994, Dec. 2023, doi: 10.3390/electronics12244994.
- [94] A. Basaure, S. Ruutu, and T. R. Casey, “Modeling Network Effects in Techno-Economic Analysis: A 5G Platform Case for Connected Vehicles,” *IEEE Commun. Mag.*, vol. 61, no. 2, pp. 64–70, Feb. 2023, doi: 10.1109/MCOM.001.2200308.
- [95] A. Chiha, M. Van Der Wee, K. Briggs, and D. Colle, “Techno-economic evaluation of a brokerage role in the context of integrated satellite-5G networks,” in *2020 6th IEEE Conference on Network Softwarization (NetSoft)*, Ghent, Belgium: IEEE, Jun. 2020, pp. 1–5. doi: 10.1109/NetSoft48620.2020.9165508.
- [96] A. V. Paz, R. R. Reyes, M. L. V. Vivas, T. Bauschert, A. Autenrieth, and J.-P. Elbers, “Techno-Economic Evaluation of Transport Network Architectures for 6G Mobile Systems,” *IEEE Commun. Mag.*, vol. 62, no. 11, pp. 28–34, Nov. 2024, doi: 10.1109/MCOM.004.2400121.
- [97] H. Cao, H. Zhao, D. X. Luo, N. Kumar, and L. Yang, “Dynamic Virtual Resource Allocation Mechanism for Survivable Services in Emerging NFV-Enabled Vehicular Networks,” *IEEE Trans. Intell. Transport. Syst.*, vol. 23, no. 11, pp. 22492–22504, Nov. 2022, doi: 10.1109/TITS.2021.3120723.
- [98] S. Quan, S. Gao, J.-S. Zhang, and J. Wu, “Virtualization, Cloudification, and Service Orientation of Network: A Systematic Review,” *Journal of Computer Science and Technology*, vol. 40, no. 3, pp. 701–730, 2025, doi: 10.1007/s11390-024-4817-6.
- [99] S. Wendt *et al.*, “Value of 6G,” in *6G to Build a Sustainable Future*, 1st ed., M. A. Uusitalo, P. Rugeland, M. R. Boldi, and A. Nimr, Eds., Wiley, 2026, pp. 9–54. doi: 10.1002/9781394363605.ch2.
- [100] Y. W. Cheng and A. Bilal, “Regulatory data privacy concerns in proliferating IoT era of telecommunication data monetisation: a systematic literature review,” *Computing*, vol. 107, no. 9, p. 190, Sep. 2025, doi: 10.1007/s00607-025-01542-8.
- [101] R. Bolla, R. Bruschi, F. Davoli, L. Ivaldi, C. Lombardo, and B. Siccardi, “An AI Framework for Fostering 6G towards Energy Efficiency,” in *2022 61st FITCE International Congress Future Telecommunications: Infrastructure and Sustainability (FITCE)*, Rome, Italy: IEEE, Sep. 2022, pp. 1–6. doi: 10.23919/FITCE56290.2022.9934697.

- [102] S. Yrjölä, M. Matinmikko-Blue, and T. Chowdhury, “Sustainable business model designs toward 6G era,” *J. Wirel. Commun. Netw.*, vol. 2026, no. 1, p. 55, Mar. 2026, doi: 10.1186/s13638-026-02600-1.
- [103] B. W. Kim and G. E. Choi, “Beyond 5G and non-terrestrial network (NTN) integrated architecture: access challenges for expanding artificial intelligence of things (AIoT),” Mar. 18, 2025. doi: 10.22541/au.174229429.93441897/v1.
- [104] C. Cimini, A. Lagorio, R. Pinto, G. Pezzotta, F. Adrodegari, and S. Cavalieri, “5G supporting digital servitization in manufacturing: An exploratory survey,” *IET Collab Intel Manufact*, vol. 5, no. 3, p. e12083, Sep. 2023, doi: 10.1049/cim2.12083.
- [105] M. N. Patwary, S. Junaid Nawaz, Md. A. Rahman, S. K. Sharma, Md. M. Rashid, and S. J. Barnes, “The Potential Short- and Long-Term Disruptions and Transformative Impacts of 5G and Beyond Wireless Networks: Lessons Learnt From the Development of a 5G Testbed Environment,” *IEEE Access*, vol. 8, pp. 11352–11379, 2020, doi: 10.1109/ACCESS.2020.2964673.
- [106] M. Magnaghi, A. Ghezzi, and A. Rangone, “Beyond the 5G License: Unveiling the Strategic Ambiguity Spectrum of Mobile Network Operators,” *R&D Management*, vol. 56, no. 1, pp. 153–167, Jan. 2026, doi: 10.1111/radm.70016.
- [107] W. Ben-Ameur, L. Cano, and T. Chahed, “A framework for joint admission control, resource allocation and pricing for network slicing in 5G,” in *2021 IEEE Global Communications Conference (GLOBECOM)*, Madrid, Spain: IEEE, Dec. 2021, pp. 1–6. doi: 10.1109/GLOBECOM46510.2021.9685847.
- [108] E. J. Sacoto-Cabrera, L. Guijarro, J. R. Vidal, and V. Pla, “Economic feasibility of virtual operators in 5G via network slicing,” *Future Generation Computer Systems*, vol. 109, pp. 172–187, Aug. 2020, doi: 10.1016/j.future.2020.03.044.
- [109] E. Borcoci, A.-M. Dragulinescu, F. Y. Li, M.-C. Vochin, and K. Kjellstadli, “An Overview of 5G Slicing Operational Business Models for Internet of Vehicles, Maritime IoT Applications and Connectivity Solutions,” *IEEE Access*, vol. 9, pp. 156624–156646, 2021, doi: 10.1109/ACCESS.2021.3128496.
- [110] P. J. Nesse, L. Gillund, and R. Gilsing, “A Collaborative Business Model for 5G/IoT Enabled Solutions in Forestry use Cases,” in *2024 IEEE International Conference on Engineering, Technology, and Innovation (ICE/ITMC)*, Funchal, Portugal: IEEE, Jun. 2024, pp. 1–9. doi: 10.1109/ICE/ITMC61926.2024.10794394.
- [111] S. K. A. Kumar and E. J. Oughton, “Infrastructure Sharing Strategies for Wireless Broadband,” *IEEE Commun. Mag.*, vol. 61, no. 7, pp. 46–52, Jul. 2023, doi: 10.1109/MCOM.005.2200698.