

УДК 330.47

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DOI: 10.32702/2306-6814.2023.1.79

ESTIMATION OF ECONOMIC EXPEDIENCY OF DEVELOPMENT OF DOMESTIC SATELLITE COMMUNICATION NETWORK BASED ON STARLINK

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ОЦІНКА ЕКОНОМІЧНОЇ ДОЦІЛЬНОСТІ РОЗВИТКУ ВІТЧИЗНЯНОЇ МЕРЕЖІ СПУТНИКОВОГО ЗВ'ЯЗКУ НА БАЗІ STARLINK

As a result of the massive rocket attacks by Ukraine, which Russia has once again carried out, as well as the associated energy cuts in the country's scale, virtually all the country's localities are currently experiencing problems with the Internet. In many locations, the infrastructure has been destroyed as a result of fighting. The outlined situation is creating significant problems in the economy, considering that by the time of military actions in the country there was a large and constantly increased Internet sector, rather than developed electronic business and electronic commerce. In addition, a system-wide multi-level structure was functioning, with a stable relationship between economic entities through the Internet. Starling terminals are currently helping to restore and maintain communications for business entities in some regions. Therefore, the research is oriented on the estimation of economic expediency of the development of a domestic satellite communication network on the base of terminals Starlink. The authors drew attention that taking into account the newest character of the project Starling Ukraine, there is a question as to the

substantiation, expediency of acquisition and operation of Starlink terminals using indicators of efficiency of investment projects, among which are: net current value, index of profitability, internal rate of return, payback period. The approach to the estimation of economic expediency of development of domestic satellite network based on Starlink has a formula taking into account the distribution of efficiency indicators of investment projects on the available types of satellite Internet networks from Starlink. Detailed indicators are reasonable in terms of: Networks of small terminals; Business terminals networks; networks of mobile terminals RV and Maritime. Comparing the effectiveness of Starlink terminals with the available network types, it is obvious that the most active development of network of Business terminal Starlink can be predicted as it provides the greatest profit for the shortest payback period.

Через масовані ракетні обстріли України, які Росія вкотре здійснила, пов'язаними з цим відключеннями електроенергії в масштабі країни, практично у всіх населених пунктах країни наразі спостерігаються перебої з Інтернетом. За даними NetBlocks, у зв'язку з окресленими факторами лише у листопаді 2022 р. трафік по всій країні впав до 35% від попереднього рівня. У багатьох населених пунктах телефонні лінії, кабелі та бездротові з'єднання для підключення комп'ютерів та інших пристроїв до всесвітньої мережі зруйновані внаслідок бойових дій. Окреслене становище формує значні проблеми в економіці, враховуючи, що до моменту військових дій у країні був великий і постійно збільшуваний інтернет-сектор, досить розвинений електронний бізнес та електронна комерція. Крім того, функціонувала системно організована засобами Інтернету багаторівнева структура, зі сталими взаємовідносинами економічних суб'єктів. Наразі відновити або підтримати зв'язок для суб'єктів економічної діяльності у деяких регіонах допомагають термінали Starlink. В Україні комерційні термінали Starlink почали з'являтися з 2020 р. Відтак дослідження зорієнтоване на оцінку економічної доцільності розвитку вітчизняної мережі супутникового зв'язку на базі терміналів Starlink. Звернено увагу, що враховуючи новітній характер "Starlink Україна", постає питання, щодо обґрунтування доцільності придбання й експлуатації терміналів Starlink за показниками ефективності інвестиційних проєктів, серед яких: чиста поточна вартість, індекс рентабельності, внутрішня норма доходності, термін окупності. Підхід до оцінки економічної доцільності розвитку вітчизняної мережі супутникового зв'язку на базі Starlink має формуватися з урахуванням розподілу показників ефективності інвестиційних проєктів за типами мереж супутникового Інтернету. Деталізація показників доцільна у розрізі: мереж невеликих терміналів; мереж Business терміналів; мереж мобільних терміналів RV та Maritime. Порівнюючи ефективність Starlink за типами мереж можна спрогнозувати найбільш активний розвиток мережі Business Starlink, оскільки вона забезпечує найбільший прибуток за найменшого терміну окупності. Додатково підвищує економічну доцільність розвитку мережі Business придатність її терміналів до відновлення повністю знищених мереж місцевого провайдера.

Key words: Starlink terminals; satellite communication, efficiency of investment projects, networks.

Ключові слова: термінали Starlink, супутниковий зв'язку, ефективність інвестиційних проєктів, мережі.

PROBLEM SETTING (DESCRIPTION OF THE PROBLEM BEING ANALYZED IN GENERAL AND ITS CONNECTION WITH IMPORTANT ACADEMIC OR PRACTICAL TASKS)

As a result of the massive rocket attacks by Ukraine, which Russia has once again carried out, as well as the associated energy cuts in the country's scale, virtually all the country's localities are currently experiencing problems with the Internet. In many settlements, the infrastructure

has been destroyed as a result of fighting. According to NetBlocks in November 2022 traffic across the country fell to 35% of the previous level [5]. Thus, the biggest problem with Internet access is in the Poltava region, where traffic is only 7% of the usual level. In addition, the difficult situation is observed in Cherkasy and Mykolaiv oblasts (8%), Odesa (12%), Zhytomyr (13%), and other oblasts [5]. The outlined situation is creating significant problems in the economy, considering that by the time of military actions in the country there was a large and constantly

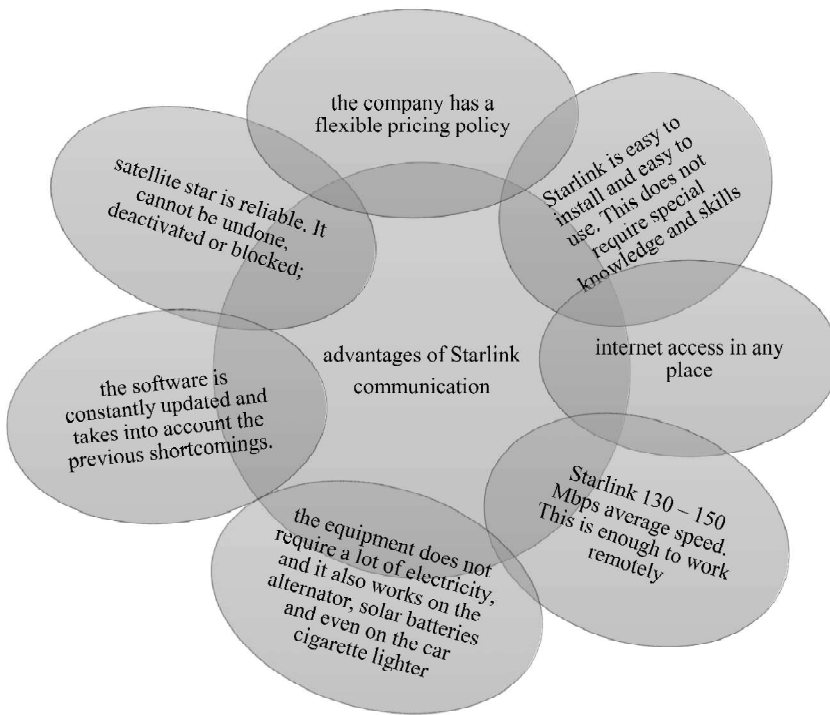


Figure 1. Advantages of Starlink satellite communication from Starlink SpaceX

Source: [3; 4].

increased Internet sector, rather than developed electronic business and electronic commerce [3; 6]. In addition, a system-wide multi-level structure was functioning, with a stable relationship between economic entities through the Internet Starlink terminals (which operate based on Starlink satellite communication complexes) are helping to restore and maintain communication for economic

This is due to the number of advantages of Starlink satellite communication and Starlink equipment (Figure 1), which, among other things, does not require a lot of electricity, therefore it operates from a generator, and solar batteries [4]. Starlink terminal network works in regions where the connection is unreliable or not available, which is especially important for economic entities involved in electronic business and electronic commerce.

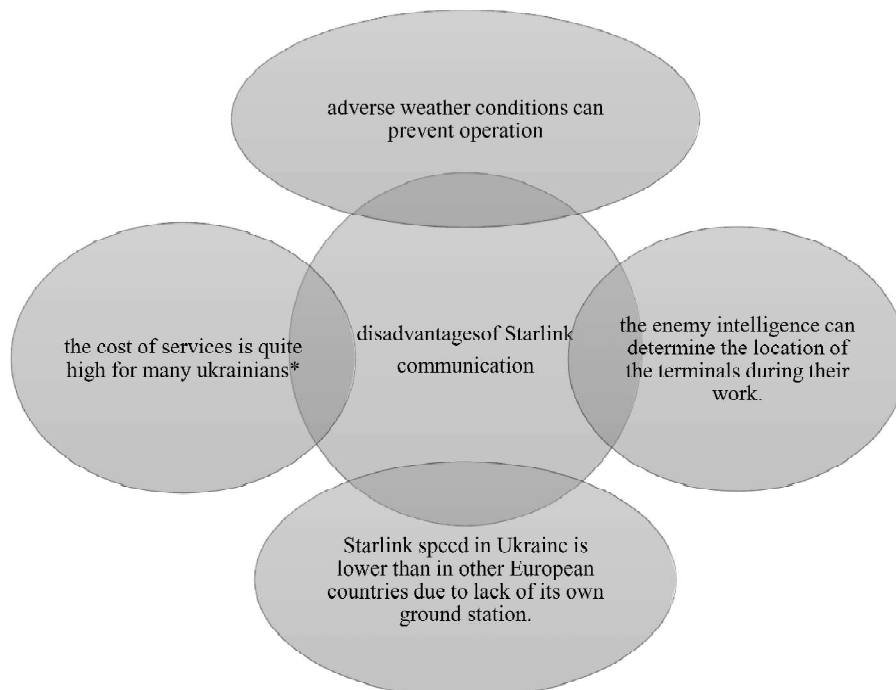


Figure 2. Disadvantages of Starlink SpaceX satellite communication

Note:

It is known that the price will not decrease even when more satellites appear on the orbit

Source: [3]

entities in some regions. Starlink project development began in 2015, and the prototypes were launched in orbit in 2018. In Ukraine, Starlink commercial terminals started to appear in 2020 The question arises as to the assessment of the economic feasibility of the development of the domestic satellite network based on Starlink in the conditions of military actions in Ukraine.

THE WORDING OF THE PURPOSES OF THE ARTICLE (PROBLEM)

The purpose of the article is to assess the economic feasibility of the development of the domestic satellite communication network based on different types of terminals Starlink.

THE PAPER'S MAIN BODY WITH FULL REASONING OF ACADEMIC RESULTS

Within the framework of this study, it's stated that as of the end of 2022, due to large-scale power cuts, the number of Starlink users has increased in Ukraine.

However, due to the shortcomings of the outlined connection (Fig.2), among which the cost of services (which is quite high for many Ukrainians) is currently active only the development of Starlink multi— user terminals, which provide access to the Internet where it is technically difficult or impossible. This is due to the fact that unlike other satellite.

For example, Starlink Ukraine registered in Ukraine on April 27, but at the moment 1000 terminals have already been operating on our territory [3; 4; 5]. The company obtained the license of the operator in early June 2022. As of the beginning of 2020 up to 300 Starlink terminals were operating in Ukraine, at the beginning of 2021 — 1000, and in 2022 — 23000. The Ministry of Information and State Special Communication is handing over terminals primarily

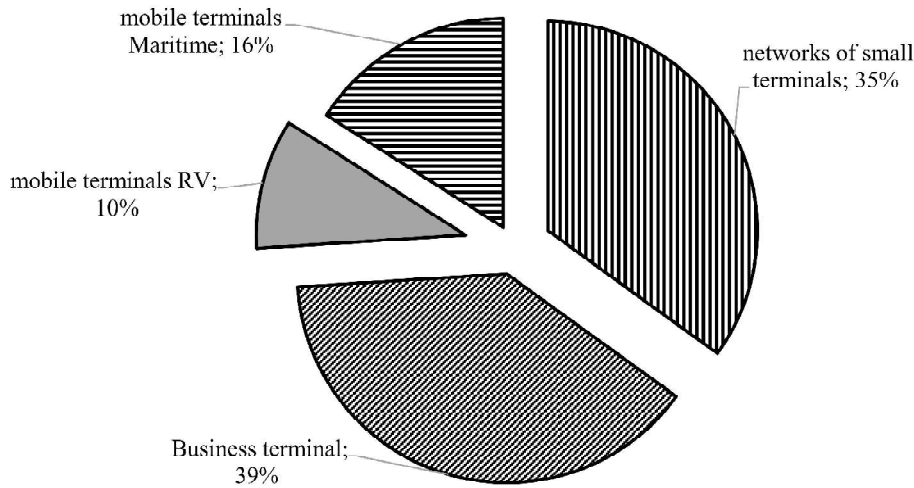


Figure 3. The structure of commercial terminals operating in Ukraine at the end of 2022

Source: Starlink SpaceX.

to military personnel, as well as to hospitals, enterprises of critical infrastructure, schools, fire units, state institutions, and volunteers. However, out of 23000 operating terminals, 55% have a commercial purpose. Internet provider Starlink differs in the presence of its satellite network.

Taking into account the newest character of the Starlink Ukraine project, there is a question as to the substantiation, expediency of commissioning and operation of Starlink terminals using indicators of efficiency of investment projects, including: net current value (NPV), index of profitability (PI), internal rate of return (IRR), payback period (DRP) [1; 2]. The expediency of such approach to the estimation of economic expediency of development of domestic satellite network based on Starlink is that such operations are also designed and directed on achievement of economic result on available types of satellite Internet networks from Starlink, namely in the following way:

- Networks of small terminals (35% of the total number of commercial terminals operating in Ukraine);
- Business terminals networks (39% of the total number of commercial terminals operating in Ukraine);
- Networks of mobile terminals RV and Maritime (26% of the total number of commercial terminals operating in Ukraine).

The structure of commercial terminals operating in Ukraine at the end of 2022 is shown in Fig. 3.

For small ones include such terminals Starlink, which can support simultaneous work of up to 6 users with a speed of the Internet from 50 to 150 Mbit/s with a possible delay of the signal from 20 to 40 milliseconds. These terminals are oriented on satellite Internet package cost \$110 per month and 5-year operation of special equipment cost \$599. The connection package includes a terminal (antenna), a Wi-Fi router, and a cable with a length of 30 meters. Currently, 4428 such terminals have been operating in Ukraine. According to the available project data according to the conditions of Ukraine as of 2022, the annual throughput of the terminal is 6000 users, with the calculation of the terminal capacity for the next years it will not change. Therefore, the basic conditions for assessing the economic feasibility of the domestic network of Starlink small terminals are given in Table 1.

According to the basic conditions of operation of a small interval, it is obvious that NVP and PI on the project of operation of small terminals Starlink > 0, and IRR project < NVP, therefore the project is expedient. Given that capital investments are equal to \$4783.222, they will be covered by the final results after 3 years of 311 days of operation.

Table 1. The basic conditions for assessing the economic feasibility of the domestic network of Starlink small terminals

years of implementation	Investments in the project, \$	Income to the project, \$	Discounting investments in the project		Discounting income to the project, \$		NVP, \$	PI, %	IRR, \$	DPP
			discounting factor	outflows	discounting factor	inflows				
0	599	-		-	1	0				
1	1320	1820	1	599	0.8496	1546.304	974,12 > 0	119,8 > 0	4783.222	3 years + 311 day
2	1320	1820	0.9091	1200	0.7219	1313.767				
3	1320	1820	0.8264	1090.909	0.6133	1116.2				
4	1320	1820	0.7513	991.736	0.5211	948.343				
5	1320	1820	0.683	901.578	0.4427	805.729				
CFP/CF				4783.222	-	5730.344				

Note:

* Discount rate for the project is 10%, average annual inflation (expectations) is 7%.

Source: Starlink SpaceX.

Therefore, 4428 small terminals operating in Ukraine can generate \$4,19 million of annual profit. This amount is significant. However, the additional economic expediency of the commissioning and operation of Starlink small terminals may affect that since August 24 Ukraine has received a special subscription fee of \$60 per month and \$385 for a package of special equipment. At the same time, it is not possible to accurately calculate the effectiveness of such projects, since the preferential price will be valid for the next revision of the tariff policy.

For large, such Starlink terminals are capable of supporting simultaneous work of up to 30 users with Internet speed from 150 to 500 Mbit/s. (Business terminals). These terminals are oriented on satellite Internet package cost \$500 and 5-level operation of special equipment cost \$2500. The connection package includes a terminal (powerful antenna), a Wi-Fi router, and a 30-meter cable. Currently, 4933 such terminals have been operating in Ukraine. According to the available project data according to the conditions of Ukraine as of 2022, the annual throughput of the terminal is 30000 users, with the calculation of the terminal capacity for the next years it will not change. Therefore, the basic conditions for the assessment of the economic feasibility of the development of a domestic network of Business Starlink terminals are given in Table 2.

According to the basic conditions of operation of a small interval, it is obvious that NVP and PI on the project of operation of small terminals Starlink > 0, and IRR project < NVP, therefore the project is expedient. Given that capital investments are equal to \$21519.193, they will be covered by the final results after 273 days of operation. Thus, 4934 terminals operating in Ukraine Business Starlink terminals can generate \$420,45 million annual profit. The operation of Business terminals is more profitable than the operation of small terminals Starlink. Further increases the economic feasibility of the development of the network of Business Starlink terminals is their suitability for the restoration of the destroyed networks of the local provider. For example, Kyivstar renewed communication in Borodyanka with Starlink equipment, Vodafone in Irpen, and Lifecell in Bucha.

Thanks to the March update Starlink in Ukraine adapted to the needs of Ukrainians. Previously Starlink was not used as a mobile access point but only operated at the activation location. However, now mobile terminals RV (1265 terminators) and Maritime (2023 terminals) have appeared, which can support simultaneous work from 6 to 25 users with a speed of Internet from 150 to 500 Mbit/s., which provides the possibility to suspend and resume work at any time, and the account is presented in a month of use. One terminal can be transported and used in different locations and even on the road.

In particular, small terminals RV Starlink solve Internet problems on the road and can support the simultaneous work of up to 6 users. The connection package includes a terminal (powerful antenna) with GPS capabilities, a Wi-Fi router, and a 30-meter cable. These terminals are oriented on satellite Internet package cost \$135 and special

Table 2. The basic conditions for the assessment of the economic feasibility of development of domestic network of Business Starlink terminals

years of implementation	Investments in the project, \$	Income to the project, \$	Discounting investments in the project		Discounting income to the project, \$		NVP, \$	PI, %	IRR, \$	DPP
			discounting factor	outflows	discounting factor	inflows				
0	2500	-			1					
1	6000	33900	1	2500	0.8496	28802.039	85216,33	496	21519.193	273 days
2	6000	33900	0.9091	5454.545	0.7219	24470.721				
3	6000	33900	0.8264	4958.678	0.6133	20790.75				
4	6000	33900	0.7513	4507.889	0.5211	17664.195				
5	6000	33900	0.683	4098.081	0.4427	15007.812				
CFP/ CF				21519.193	-	106735.525				

Note:

* Discount rate for the project is 10%, average annual inflation (expectations) is 7%.

Source: Starlink SpaceX.

equipment cost \$599. According to the available project data according to the conditions of Ukraine as of 2022, the annual throughput of the terminal is 7000 users, with the calculation of the terminal capacity for the next years it will not change. The basic conditions for the assessment of the economic feasibility of the development of domestic network RV Starlink terminals are given in Table 3. According to the basic conditions of operation of a small interval, it is obvious that NVP and PI on the project of operation of small terminals Starlink > 0, and IRR project < NVP, therefore the project is expedient. Given that capital investments are equal to \$5734.182, they will be covered by the final results after 3 years and 76 days of operation. Therefore, 1265 existing terminals in Ukraine RV Starlink can generate \$2,5 million of annual profit.

At that, Maritime terminals solve Internet problems on the road, and in the sea and can support the simultaneous work of up to 25 users. The connection package includes a terminal (powerful antenna) with GPS capabilities, a Wi-Fi router, and a 30-meter cable. These terminals are oriented on satellite Internet package cost \$5000 and special equipment cost \$10 000. According to the available project data according to the conditions of Ukraine as of 2022, the annual permeability of the terminal is 60000 persons, with the

Table 3. The basic conditions for the assessment of economic feasibility of development of domestic network RV Starlink terminals

years of implementation	Investments in the project, \$	Income to the project, \$	Discounting investments in the project		Discounting income to the project, \$		NVP, \$	PI, %	IRR, \$	DPP
			discounting factor	outflows	discounting factor	inflows				
0	599				1					
1	1620	2500	1	599	0.8496	2124.044	2137,17	1,37	5734.182	3 years + 76 days
2	1620	2500	0.9091	1472.727	0.7219	1804.625				
3	1620	2500	0.8264	1338.843	0.6133	1533.242				
4	1620	2500	0.7513	1217.13	0.5211	1302.669				
5	1620	2500	0.683	1106.482	0.4427	1106.771				
CFP/ CF				5734.182		7871.351				

Note:

* Discount rate for the project is 10%, average annual inflation (expectations) is 7%.

Source: Starlink SpaceX.

Table 4. The basic conditions for assessing the economic feasibility of development of the domestic network of Maritime Starlink terminals

years of implementation	Investments in the project, \$	Income to the project, \$	Discounting investments in the project		Discounting income to the project, \$		NVP, \$	PI, %	IRR, \$	DPP
			discounting factor	outflows	discounting factor	inflows				
0	10000				1					
1	60000	97110	1	10000	0.8496	82506.37				
2	60000	97110	0.9091	54545.455	0.7219	70098.87				
3	60000	97110	0.8264	49586.777	0.6133	59557.24				
4	60000	97110	0.7513	45078.888	0.5211	50600.88				
5	60000	97110	0.683	40980.807	0.4427	42991.4				
CFP/ CF				200191.927		305754.7	105562,9	1,53	200191.927	2 years + 292 days.

Note:

* Discount rate for the project is 10%, average annual inflation (expectations) is 7%.

Source: Starlink SpaceX.

Table 5. Comparing the effectiveness of Starlink terminals by the available network types, at the end of 2022

Terminal network	Number of terminals in the network, units	Total network profitability per year, \$million	Return on investment, years/days
Terminal network Maritime Starlink	2023	213,55	2 years + 202 day
Terminal network RV Starlink	1265	2,5	3 years + 76 days
Small network network Starlink	4428	4,19	3 роки 311 days
Terminal Business network Starlink	4933	420,45	273 days

Source: Starlink SpaceX and tables 1—4.

calculation of the terminal capacity for the next years it will not change. The basic conditions for assessing the economic feasibility of the development of the domestic network of Maritime Starlink terminals are given in Table 4. According to the basic conditions of operation, it is obvious that NVP and PI are on the project of operation of outlined terminals Starlink >

0, and IRR project < NVP, therefore the project is expedient. Given that capital investments are equal to \$200191.927, they will be covered by the final results after 2 years and 202 days of operation. Therefore, 2023 terminals operating in Ukraine Maritime Starlink can generate \$213,55 million of annual profit (despite the greater profitability of less than businesses of Starlink terminals).

Comparing the effectiveness of Starlink terminals by the available network types (Table. 4) it is obvious that one can predict the most active development of Terminal businesses network Starlink, which provides the largest profit in the shortest payback period.

The conclusions confirm the network share in the average growth rate for 5 (five) years comparison (Figure 4).

The above provisions allow stating that an approach to the estimation of economic expediency of development of a domestic satellite network based on Starlink should be formed account the distribution of indicators of efficiency of investment projects on available types of satellite Internet networks from Starlink.

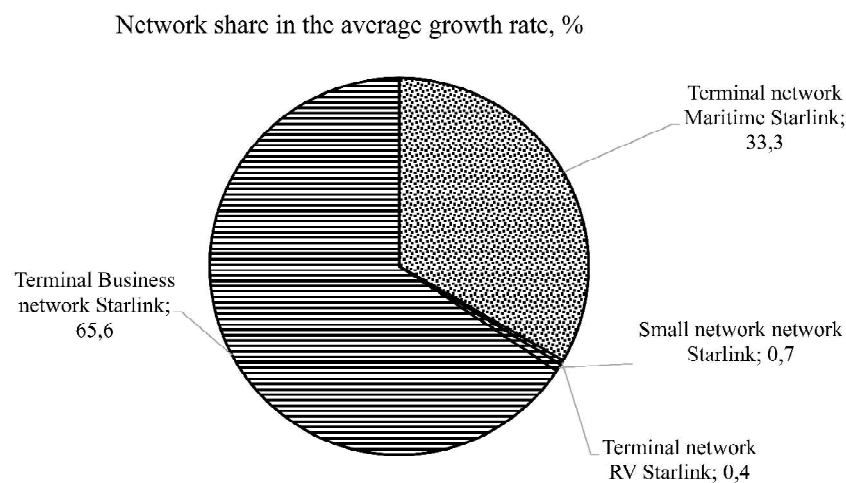


Figure 4. The conclusions confirm the network share in the average growth rate comparison for 5 (five) years., %

Source: Starlink SpaceX and tables 1—4.

SUMMARY RESEARCH SUMMARY AND PROSPECTS FOR FURTHER TASKS IN THIS AREA

Due to large-scale power cuts in Ukraine, the number of Starlink users has increased. Starlink terminal network works in regions where the connection is unreliable or not available, which is especially relevant for national economic entities. According to the results of the study, the following conclusions were made:

1. As of the beginning of 2020 up to 300 Starlink terminals were operating in Ukraine, at the beginning of 2021 — 1000, and in 2022 — 23000 (of which 55% have a commercial purpose). Taking into account the newest character of the Starlink Ukraine project, there is a question as to the substantiation, expediency of commissioning and operation of Starlink terminals using indicators of efficiency of investment projects, including: net current value, index of profitability, internal rate of return, payback period (DRP).

2. The approach to the estimation of the economic feasibility of the development of a domestic satellite network based on Starlink formed an account of the distribution of performance indicators of investment projects on the existing types of satellite Internet networks from Starlink. Detailed indicators are reasonable in terms of: Networks of small terminals; Business terminals networks; networks of mobile terminals RV and Maritime.

3. Comparing the effectiveness of Starlink terminals with existing network types, it is obvious that the most active development of Business terminal networks Starlink, which provides the greatest profit in the shortest payback period, can be predicted. Further increasing the economic feasibility of the development network of Business Starlink terminals is their suitability for the restoration of the destroyed networks of the local provider.

The perspectives of further research consist in its use to justify the economic expediency of establishing communication between Ukrainian mobile operators in the settlements where the infrastructure was destroyed as a result of fighting.

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Стаття надійшла до редакції 20.12.2022 р.

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