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DEFINITION OF ECONOMIC EFFICIENCY OF ICT INFRASTRUCTURE CO-DEPLOYMENT WITH ROAD TRANSPORT AND ENERGY INFRASTRUCTURE

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ВИЗНАЧЕННЯ ЕКОНОМІЧНОЇ ЕФЕКТИВНОСТІ СПІЛЬНОГО РОЗГОРТАННЯ ІНФРАСТРУКТУРИ ІКТ ІЗ ДОРОЖНО-ТРАНСПОРТНОЮ ТА ЕНЕРГЕТИЧНОЮ ІНФРАСТРУКТУРОЮ

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ОПРЕДЕЛЕНИЕ ЭКОНОМИЧЕСКОЙ ЭФФЕКТИВНОСТИ СОВМЕСТНОГО РАЗВЁРТЫВАНИЯ ИНФРАСТРУКТУРЫ ИКТ С ДОРОЖНО-ТРАНСПОРТНОЙ И ЭНЕРГЕТИЧЕСКОЙ ИНФРАСТРУКТУРОЙ

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Abstract. As more of the world becomes digital, broadband access becomes more important than ever, including in rural and remote areas. National programmes to develop the information and communications technology (ICT) infrastructure and reduce the digital divide are recognized as essential to the achievement of national socioeconomic development plans. However, for telecom operators, laying fibre-optic cables in sparsely populated regions is not always economically viable, and the existing telephone network in many regions is not adapted to provide broadband access to the Internet. The economic cost and resources used to deploy the ICT infrastructure could be optimized through co-deployment, which is defined as the concomitant deployment of ducts and/or fibre-optic cables during the construction of infrastructure such as new roads, highways, railways, power transmission lines and oil/gas pipelines. At the same time, the issues of assessing the economic efficiency of the co-deployment of telecommunications with other infrastructure services within the framework of one project remain insufficiently resolved. The aim of the work is formation of a method of an estimation of efficiency co-deployment with road transport and energy infrastructure. The article is comprised of the following components: overview of methodology for determining the compatibility potential of ICT infrastructure co-deployment with road transport and energy infrastructure; a parametric model of ICT infrastructure co-deployment with road transport and energy infrastructure; methodology for assessing the economic efficiency of ICT infrastructure co-deployment with road transport and energy infrastructure. The subject of the research is the process of ICT infrastructure co- deployment with road transport and energy infrastructure. The scientific novelty of the work consists in the development of methodology that is based on the principle of comparing an indicator of the speed of a specific increment in value for cases of co-deployment and separate deployment of the corresponding infrastructures.

Key words: co-deployment, economic efficiency, ICT, road transport, energy, fibre-optic, infrastructure, indicator of the speed of a specific increment in value, net present value.

Анотація. Оскільки більша частина світу стає цифровою, широкосмуговий доступ є як ніколи важливим, у тому числі у сільській та віддаленій місцевості. Національні програми з розвитку інфраструктури інформаційно-комунікаційних технологій (ІКТ) та зменшення цифрового розриву визнані важливими складовими національних планів соціально-економічного розвитку. Однак для операторів зв'язку прокладка волоконно-оптичних кабелів у малонаселених регіонах не завжди є економічно вигідною, а існуюча телефонна мережа в багатьох регіонах не пристосована для забезпечення широкосмугового доступу до Інтернету. Економічні витрати та ресурси, що використовуються для розгортання ІКТ-інфраструктури, можуть бути оптимізовані за допомогою спільного розгортання, яке визначається як одночасне розміщення кабельної каналізації та/або волоконно-оптичних кабелів під час будівництва нових доріг, шосе, залізниць, ліній електропередачі та нафтогазопроводів. Водночас, питання оцінки економічної ефективності спільного розгортання телекомунікацій з іншими інфраструктурними об'єктами в рамках одного проекту залишаються недостатньо вивченими. Мета статті – розробка методики оцінки ефективності спільного розгортання інфраструктури ІКТ з дорожньо-транспортною та енергетичною інфраструктурою. Стаття складається з таких компонентів: огляд методики визначення потенціалу сумісності спільного розгортання інфраструктури ІКТ з дорожньо-транспортною та енергетичною інфраструктурою; параметрична модель спільного розгортання інфраструктури ІКТ з дорожньо-транспортною та енергетичною інфраструктурою; методика оцінки економічної ефективності спільного розгортання інфраструктури ІКТ з дорожньо-транспортною та енергетичною інфраструктурою.

Ключові слова: спільне розгортання, економічна ефективність, ІКТ, транспорт, енергетика, волоконно-оптичні лінії, інфраструктура, показник швидкості питомого приросту вартості, чистий грошовий потік.

Аннотация. Поскольку большая часть мира становится цифровой, широкополосный доступ является как никогда важным, в том числе в сельской и отдаленной местности. Национальные программы по развитию инфраструктуры информационно-коммуникационных технологий (ИКТ) и сокращению цифрового разрыва признаны важными составляющими национальных планов социально-экономического развития. Однако для операторов связи прокладка волоконно-оптических кабелей в малонаселенных регионах не всегда является экономически выгодной, а существующая телефонная сеть во многих регионах не приспособлена для обеспечения широкополосного доступа к Интернету. Экономические затраты и ресурсы, используемые для развертывания ИКТ-инфраструктуры, могут быть оптимизированы с помощью совместного развертывания, которое определяется как одновременное размещение кабельной канализации и/или волоконно-оптических кабелей при строительстве новых дорог, шоссе, железных дорог, линий электропередачи и нефтегазопроводов. В то же время, вопросы оценки экономической эффективности совместного развертывания телекоммуникаций с другими инфраструктурными объектами в рамках одного проекта остаются недостаточно изученными. Цель статьи – разработка методики оценки эффективности совместного развертывания инфраструктуры ИКТ с дорожно-транспортной и энергетической инфраструктурой. Статья состоит из следующих компонентов: обзор методики определения потенциала совместимости совместного развертывания инфраструктуры ИКТ с дорожно-транспортной и энергетической инфраструктурой; параметрическая модель совместного развертывания инфраструктуры ИКТ с дорожно-транспортной и энергетической инфраструктурой; методика оценки экономической эффективности совместного развертывания инфраструктуры ИКТ с дорожно-транспортной и энергетической инфраструктурой.

Ключевые слова: совместное развертывание, экономическая эффективность, ИКТ, транспорт, энергетика, волоконно-оптические линии, инфраструктура, показатель скорости удельного прироста стоимости, чистый денежный поток

A problem statement and analysis of recent research and publications. As more of the world becomes digital, broadband access becomes more important than ever, including in rural and remote areas. National programmes to develop the information and communications technology

(ICT) infrastructure and reduce the digital divide are recognized as essential to the achievement of national socioeconomic development plans.

However, for telecom operators, laying fibre-optic cables in sparsely populated regions is not always economically viable, and the existing telephone network in many regions is not adapted to provide broadband access to the Internet. The economic cost and resources used to deploy the ICT infrastructure could be optimized through co-deployment, which is defined as the concomitant deployment of ducts and/or fibre-optic cables during the construction of infrastructure such as new roads, highways, railways, power transmission lines and oil/gas pipelines [1,2].

The issues of scientific substantiation and applied mechanisms for effectiveness estimation of various processes have been studied in many scientific works. So, in [3] the analysis of the theoretical foundations of efficiency is carried out, in [4] the methodological foundations for assessing and managing the efficiency of an enterprise are developed. The issues of theoretical substantiation, methodological support and applied regulation of the economic efficiency of the functioning and development of enterprises in the communications sector are over-viewed in works [5-6] and others.

The applied issues of joint regional deployment of ICT infrastructure with other infrastructure projects are actively studied in [7-9] and other sources.

At the same time, the issues of assessing the economic efficiency of the co-deployment of telecommunications with other infrastructure services within the framework of one project remain insufficiently resolved.

The information base of the research is the international and national legislative and regulatory acts that relate to the issues under study, data from international scientific platforms, as well as official statistical information. To achieve the designated goal, a number of methods of scientific knowledge have been applied, namely: theoretical generalization - for critical analysis and systematization of research material; comparison - to compare data; abstraction - to highlight the properties of the system, which are the object of this study; economic and mathematical - to develop a methodological approach to assessing efficiency.

Presentation of the main material of the research. The main factors stimulating the co-deployment and sharing of infrastructure are economic benefits and requirements for the efficient use of limited resources. Economic benefits encourage operators of different infrastructure networks to cooperate in deployment or sharing of a joint infrastructure due to potential cost savings or accelerated market entry.

In response to the needs of member States, the Secretariat of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) has taken significant steps to develop human capital and create a package of useful knowledge products and tools to promote an enabling environment for ICT infrastructure co-deployment with transport and energy infrastructure. This includes organization of relevant consultations and training workshops, as well as cross-country and in-depth national studies.

One of such steps on this way was the development of capacity building toolkit as part of the in-depth national studies on ICT infrastructure co-deployment with road transport and energy infrastructure in Kazakhstan and Kyrgyzstan (Kaptur V.A., Kniazeva O.A. and others). This toolkit proposes methodologies and tools for assessing and planning the economic and organizational aspects and technical aspects of ICT infrastructure co-deployment with road transport and energy infrastructure. The toolkit is comprised of the following methodologies and tools:

– Methodology for determining the compatibility potential of ICT infrastructure co-deployment with road transport and energy infrastructure. This potential is defined through an evaluation of key parameters using a scoring system of either points or percentages;

– A parametric model of ICT infrastructure co-deployment with road transport and energy infrastructure. This model assesses the cost difference between separate deployment of infrastructure (ICT, road transport or electricity) and their co-deployment;

– Methodology for assessing the economic efficiency of ICT infrastructure co-deployment with road transport and energy infrastructure. This methodology is based on the principle of comparing an indicator of the speed of a specific increment in value for cases of co-deployment and separate deployment of the corresponding infrastructures;

– Methodology for identifying road transport and energy infrastructure projects that could include ICT infrastructure co-deployment. This methodology is based on hierarchy analysis, which consists of calculating a weighted indicator based on point estimates of several criteria and their weight coefficients, calculated by pairwise comparison;

– Content of a typical design project together with initial data form templates for the design of ICT infrastructure co-deployment with road transport and energy infrastructure.

One of the proposed methodologies is to determine the compatibility potential of ICT infrastructure co-deployment with road transport and energy infrastructure. This potential is defined through an evaluation of key parameters for the operation of infrastructure elements that have fundamental importance for co-deployment. The key parameters to identify whether infrastructures are compatible for co-deployment are proposed and categorized by technical, geographical, organizational and socioeconomic factors. These parameters are assessed and compared using a scoring system of either points or percentages. To demonstrate the application of this methodology, an evaluation of several promising ICT, road transport and energy infrastructure projects in Kazakhstan and Kyrgyzstan are conducted using the proposed parameters to see if the various infrastructure projects are compatible for co-deployment.

The procedures for this evaluation include the following:

1. Identify key factors that affect co-deployment, such as technical, legal, environmental, social, organizational, geographical, economic, marketing and other factors. Proposed key factors and parameters to determine the compatibility potential of ICT infrastructure co-deployment with road transport and energy infrastructure:

– technical factor (dependency of infrastructure on the availability of electricity; service life of infrastructure);

– geographical factor (extent to which the various infrastructure routes coincide; influence by climatic and weather conditions, geodetic, and other features on infrastructure construction and operation);

– organizational factor (regulatory support for infrastructure co-deployment; number of approvals required for infrastructure co-deployment compared with separate deployment; presence of specialists with knowledge and skills in co-deployment in infrastructure project teams; form of ownership (public or private) of the planned infrastructure project; level of complexity in infrastructure management);

– socioeconomic factor (level of difficulty in the technological process of addressing terrain challenges; social or military (defense) significance of the infrastructure; amount of additional opportunities gained from infrastructure co-deployment, including quality improvement).

2. Evaluate each key factor according to a system that involves the scoring of parameters. For example, the technical factor can be evaluated using parameters such as the dependency of infrastructure on the availability of electricity and the service life of infrastructure. An evaluation table that presents the scoring of parameters is created. Assess and compare the parameters using points or percentages. The assessment using points is based on calculation of the permissible deviation of the average values (ΔKF). The average value gives an average indication of the compatibility of the infrastructure projects while levelling out possible incompatibility or low compatibility for certain parameters.

3. Next, a parametric model of compatibility (formalized description of the communicative behavior of a combination of factors, parameters and signs) is formed by which the co-deployment is carried out. The given parametric model makes it possible to determine separately those parameters that are compatible to one degree or another. Some key factors and parameters that can be used to determine the compatibility potential of ICT infrastructure co-deployment with road transport and energy infrastructure.

The proposed methodology for assessing the economic efficiency of ICT infrastructure co-deployment with road transport and energy infrastructure is based on the comparison of an indicator of the speed of a specific increment in value for cases of co-deployment and separate deployment of the corresponding infrastructures. The indicator of the speed of a specific increment in value is the ratio of net cash flow to the product of the billing period from the start of the project to its end and the volume of investment for the current year.

The basis for assessing the economic efficiency of ICT infrastructure co-deployment with road transport or energy infrastructure is the comparison of an indicator of the speed of a specific increment in value (IS) for cases of co-deployment and separate deployment of the corresponding infrastructures.

We will consider that co-deployment is more profitable than separate deployment if the condition is fulfilled. That is, the speed of the specific increment in value in case of ICT infrastructure co-deployment with road transport or energy infrastructure is more than the average speed of similar indicators for separate deployment:

$$IS_{co\text{-}deployment} > (IS_{ICT} + IS_{transport}) / 2.$$

ISco-deployment is the indicator of the speed of a specific increment in value for ICT infrastructure co-deployment with road transport or energy infrastructure;

ISICT is the indicator of the speed of a specific increment in value for separate deployment of the ICT infrastructure; and

IStransport is the indicator of the speed of a specific increment in value for separate deployment of the road transport or energy infrastructure.

To calculate the indicator of the speed of a specific increment in value for any of the three options, the following formula is used:

$$IS = NPV / (n \times I),$$

NPV is the net present value, currency unit (cu);

n is the estimated period from the start of the project to its completion, years;

I is the investments of the current year, cu.

The NPV can be calculated using the following formula:

$$NPV = CF_{disc} – K,$$

CFdisc is the value of the discounted cash flow (CF), cu;

K is the capital costs (investments) calculated as the sum of costs according to Table 12 for the corresponding infrastructure, cu.

In this case, the discounted CF can be calculated using the following formula:

$$CF_{disc} = CF \times k_j,$$

CF is the cash flow, cu;

kj is the discount coefficient, which is calculated using the formula: $k_j = 1 / (1 + K_{disc})^j$, where Kdisc is based on the project risk level, inflation level, national bank refinancing rate, etc., and j is the time period (j = 1…n), years.

In turn, to calculate the CF, the following formula is used:

$$CF = NP + D,$$

NP is the net profit from the project for one year, cu;

D is the depreciation of fixed assets for one year, cu.

To calculate net profit (as the difference between profit and income tax), the following formula is used:

$$NP = P \times (1 - Tax),$$

P is the expected annual profit from the project, cu;

Tax is the income tax rate (from 0 to 1).

The annual profit is calculated using the following formula:

$$P = AI – Poper,$$

AI is the net annual income, cu;

Poper is the amount of annual operating costs associated with the implementation of the project.

In turn, the net annual income can be defined as:

$$AI = EP – VAT,$$

EP is the expected amount of annual revenues from the operation of the ICT, transport or energy infrastructure, or from their co-deployment, cu;

VAT is the amount of value-added tax payable, cu.

The sequence of calculation for the expected amount of annual revenues from operation of the ICT infrastructure is given in Table 1.

Table 1 – Sequence of calculation for the expected amount of annual revenues from operation of the ICT infrastructure

Indicator	Formula
Potential constant demand from the local population (PCDlp)	PCDlp = dt ×Ai × dlps × Pr dt is the proportion of the population's expenses for communications services; Ai is the average incomes of the population (in national or other currency); dlps is the proportion of the solvent population (age 18 to 65 years); and Pr is the region's population
Potential probable demand from the local population (PPDlp)	PPDlp = dt × Ai × dlps × Pr × (1 + Kdi) Kdi is the possibility of increasing demand.
Coefficient considering the demand for ICT services from children supported by parents (Kch)	Kch = dch × Pr × (1 - Pb) × dt × Ai dch is the proportion of children aged 7-18 years; Pr is the region's population; Pb is the proportion of content not received by children due to parental control; dt is the proportion of the population's expenses for communications services; and Ai is the average incomes of the population (in national or other currency)

Coefficient considering the demand for ICT services from the older age group (Kold)	Kold = dold × Pr × Pold × dt ×Ai dold is the proportion of the population over 65 years old; Pr is the region's population; Pold is the average share of content used by this age category compared to base group content; dt is the proportion of the population's expenses for communications services; and Ai is the average incomes of the population (in national or other currency)
Coefficient considering the presence of regular demand from tourists (Kt)	Kt = Qt × Ec Qt is the number of tourists; and Ec is the average cost of communications services for this category of users.
Competitive factor (Co)	Co = Scc × dt × Ai + 0.5Scs × dt × Ai Scc is the proportion of users who use the services of competitors (or alternative forms of communications) and do not plan to change operator; Scs is the proportion of users who simultaneously use the services of several operators (based on the ratio of costs for communications services 50/50); dt is the proportion of the population's expenses for communications services; and Ai is the average incomes of the population (in national or other currency)
Expected amount of annual revenues (EP)	EP = 12 (PPDlp + Kch + Kold + Kt – Co)

The sequence of calculation for the expected amount of annual revenues from operation of the road transport or energy infrastructure is given in Table 2.

Table 2 – Sequence of calculation for the expected amount of annual revenues from operation of the road transport or energy infrastructure

Indicator	Formula
Traffic revenue (Rtr)	Rtr = Rtrav × Li Rtrav is the average revenues per kilometre of road from traffic; and Li is the length of the road
Potential constant demand from the local population (PCDlp)	PCDlp = dt ×Ai × H dt is the proportion of household expenses for transport and electricity services; Ai is the average incomes of the population (in national or other currency); and H is the number of households in the region.

Potential ongoing demand for transport and electricity services from businesses (PCSв)	$PCSв = \sum_{i=1}^{n} QE_i \times E_i$ QEi is the business unit; Ei is the average monthly expenses of the i-th business unit for transport and electricity services; and n is the number of business units
Coefficient considering the presence of regular demand from tourists (Kt)	Kt = Qt × Ec Qt is the number of tourists; and Ec is the average cost of transport and electricity services for this category of users.
Competitive factor (Co)	Co = Ti × dt × St + Ti × de × Se St is the proportion of users who use several types of transport (personal, horse-drawn, etc.); Se is the proportion of users who simultaneously use different types of energy supply (generators, solar, wind, etc.); dt is the average cost of transport services; de is the average cost of electricity services; and Ti is the total number of households and business units
General demand (GD)	GD = Rtr + PCDlp + PCSв
Expected amount of annual revenues (EP)	EP = 12 (GD + Kt – Co)

The sequence of calculation for the expected amount of annual revenues from ICT infrastructure co-deployment with road transport or energy infrastructure is given in Table 3.

Table 3 – Sequence of calculation for the expected amount of annual revenues from ICT infrastructure co-deployment with road transport or energy infrastructure

Indicator	Formula
Traffic revenue (Rtr)	Rtr = Rtrav × Li Rtrav is the average revenues per kilometre of road from traffic; and Li is the length of the road.
Potential constant demand from the local population (PCDlp)	PCDlp = dt × Ai × dlps × Pr dt is the proportion of the population’s expenses for communications services; Ai is the average incomes of the population (in national or other currency); dlps is the proportion of the solvent population (age 18-65 years); and Pr is the region’s population.
Potential probable demand from the local population (PPDlp)	PPDlp = dtc × Ai × dlps × Pr × Kdi Kdi is the possibility of increasing demand, and therefore, the cost of transport and communications services in case of quality

	improvement.
Coefficient considering the demand for transport and communications services from the older age group (Kold)	Kold = dold × Pr × Pold × dtc × Ai dold is the proportion of the population over 65 years old; Pr is the region's population; Pold is the average proportion of transport and communications services used by this age category (the demand for similar services for people aged 18 to 65 is taken as 100 per cent); dtc is the proportion of the population's expenses for transport and communications services; and Ai is the average incomes of the population (in national or other currency)
Coefficient considering the presence of regular demand from various tourists (Kt)	Kt = Qt × Ec Qt is the number of tourists; and Ec is the average expenses for transport and communications services for this category of users
Coefficient considering the demand for ICT services from children supported by parents (Kch)	Kch = dch × Pr × (1 – Pb) × dt × Ai dch is the proportion of children aged 7-18 years; Pr is the region's population; Pb is the share of content not received by children due to parental control; dt is the share of the population's expenses for communications services; and Ai is the average incomes of the population (in national or other currency)
The coefficient considering the provision of regional services to social services (medical, financial, educational and other organizations) in terms of their average remoteness from settlements (Tsi)	Tsi = dmcs × Pr × dt × Ai dmcs is the proportion of the population who regularly receive medical, financial, educational and other services at a considerable distance from home; Pr is the region's population; dt is the proportion of the population's expenses for transport services; and Ai is the average incomes of the population (in national or other currency)
The coefficient considering the presence of the population's own transport, which reduces the demand for transport infrastructure services (OwnT)	OwnT = dot × Pr × dt × Ai dot is the proportion of the population with own transport; Pr is the region's population; dt is the share of the population's expenses for transport services; and Ai is the average incomes of the population (in national or other currency)
Expected amount of annual revenues (EP)	EP = 12 (Rtr + PPDlp + Kold + Kt + Kch + Tsi – OwnT)

A special calculator tool (in *.xlsx format) using the above methodology is available at [10].

Conclusions. During the formation of the scientific and methodological base for determining the economic efficiency of the co-deployment of the infrastructure of information and communication technologies with road transport and energy infrastructure, an appropriate set of methodological tools was formed and a sequence for calculating the expected financial results in the case of separate and co-deployment was proposed.

In the framework of their work, the authors concluded that co-deployment is in most cases more cost-effective. However, it should be noted that it has several problematic points, namely:

– difficulties in legal coordination, especially when deploying a project on the territory of different countries;

– the need for the formation of additional design documents and the simultaneous involvement of specialists of different specialties in design and, in the future, construction work;

– higher risks of financial failures in the absence of the expected income from all or some types of involved types of infrastructures (for example, in the event of a change in the geopolitical situation, the emergence of alternative routes or modes of communication and transport, etc.);

– a high degree of influence of macro- and mesoeconomic trends on the discounting of cash flows, which can lead to an increase in the payback period (as opposed to the calculated ones).

Further scientific developments of the authors will be aimed at the formation of a scientific basis and applied approaches that can solve the above-described problems of co-deployment of various types of infrastructures within one project, as well as form the optimal mechanisms of their interaction.

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