Economic Journal, Special Issue 1, 2022

Implications of New Technologies and Methods on Interoperability

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Abstract. The paper deals with technological implications for a regional railway network, on the example of the ECO Railway Network (ERN). The magnitude of such impact is directly related to automation and interoperability in railways. From that stance, potential implications were studied from the two perspectives: (i) technological, to see whether the efficiency of railway network changes with the advent of new technologies and (ii) technical, to see the level of the interoperability among regional railway networks to support the railway technological upswing. The paper asserts that the efficiency is one of potential implications of new technologies in railway. The latter has been examined in the context of infrastructure of the ERN. Specifically, technological implications for the ERN resulted in changing its efficiency. Also, the ECO Transport Network (ETN) has been examined against implications for its efficiency driven by new innovations. The implications for the latter have proved to be insignificant because the ETN largely remains dependent on economies of scale. In other words, the transport network performance will always negatively correlate to the increase in the quantity of network users (Shaofeng, 2013). On the other side of the spectrum, the implications for the ERN proved visible as is efficiency increased when new innovations solutions were in. From the technical perspective, the interoperability has been considered as a tool to initiate the influx of new technological solutions in the ERN at the back of the current stage of the development of the overall ETN. The paper resulted in developing the interoperability model for coordination of railway operations in the region to increase efficiency at technical level.

Keywords: New innovations, interoperability, solutions, railway routes, efficiency, train control system, radio block centre, central dispatch system, traffic management platform.

1. Technological Implications: Innovations and performance on transport infrastructure and logistics

In exploring the technological implications in the context of new innovations in railway as applied to the regional railway network of the Economic Cooperation Organization (ECO), the paper stems from the understanding that 'innovations are part of transport infrastructure and logistics' (Ferrari, 2018). In that regard, the paper first looks into where ECO countries stand in global performance on transport infrastructure and logistics. According to previous year's ranking, Türkiye, Iran and Kazakhstan were amongst the top ECO countries by performance on infrastructure and logistics. The input data for ranking in ECO was derived from World Bank's Logistics Performance Index set for year 2018. In overall, the ECO's top ranking countries in transport infrastructure and logistics staged 60 out of 103 of the ECO regional average with the collective score of 2.6 for the region. Taken separately, Türkiye came to be the highest performing country in this area holding the 47th rank, Iran 64th, and Kazakhstan 71st. Figure 1 reflects the ECO countries' performance on infrastructure and logistics in 2018. Having identified the positioning of countries in the ECO region, the paper will now explore how new innovations in railway, basing on the regional countries' performances in transport infrastructure and logistics, can influence the ECO Railway Network at the broader regional level.

Table 1: Performance of ECO countries on transport infrastructure and logistics

Top ranks	Country	Year	LPI Rank	LPI Score	Customs	Customs	INFRA	INFRA	Int shipments	Int shipments	Logistics competence	Logistics competence	Tracking/T racing	Tracking/T racing	Timeliness	Timeliness
	Afghanistan	2018	160	1.95	158	1.73	158	1.81	152	2.1	158	1.92	159	1.7	153	2.38
	Azerbaijan	2018	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2	**Iran**	2018	64	2.85	71	2.62	63	2.77	79	2.76	62	2.84	85	2.77	60	3.36
3	**Kazakhstan**	2018	71	2.81	65	2.66	81	2.55	84	2.73	90	2.58	83	2.78	50	3.53
	Kyrgyzstan	2018	108	2.55	55	2.75	103	2.38	138	2.22	114	2.36	99	2.64	106	2.94
	Pakistan	2018	122	2.42	139	2.12	121	2.2	97	2.63	89	2.59	136	2.27	136	2.66
	Tajikistan	2018	134	2.34	150	1.92	127	2.17	133	2.31	116	2.33	131	2.33	104	2.95
1	**Turkey**	2018	47	3.15	58	2.71	33	3.21	53	3.06	51	3.05	42	3.23	44	3.63
	Turkmenistan	2018	126	2.41	111	2.35	117	2.23	136	2.29	120	2.31	107	2.56	130	2.72
	Uzbekistan	2018	99	2.58	140	2.1	77	2.57	120	2.42	88	2.59	90	2.71	91	3.09

1.2 Statement of the purpose: Technological and technical implications of new innovations for railway

There exists an opinion that the new innovations in railway, including high speed rail (HSR), intelligent railway, and others, may not be needed in developing countries for the reason that they require heavy investment. The latter becomes a deadweight burden on the developing countries' public budgets. There were instances where some developing countries, Indonesia among others, took considerable time to eventually accept the loans under the large-scale HSR projects (Chew, 2015). Indeed, the innovations mostly come from advanced countries in their search for new expansive markets (Sergeeva, 2018). The quest for ways of minimizing the costs associated with bringing in new innovations to railway has remained acute, as ever. Even in advanced countries, HSR, along with some other innovative railway projects, may turn out to be complex in order to fully align the innovative transit plans with existing regulatory requirements, local stakeholder opposition, and a polarized political environment in the countries initiating such innovations (Rockwood, 2018). And yet, HSR is only one of much broader expanse of new innovations in railway. To that end, wouldn't it be reasonable to apply the new innovative products instead of comprehensive mega projects, such as HRS, which requires mass investment, new skill, and lengthy time to implement (Shunquan). As an alternative, which is less painful, the new innovative solutions (applications) may well serve the specifically-tailored needs of developing countries. Those could well-fit those countries that are currently undergoing their transition onto the mid-to-advanced level in their development paths. To that effect, this paper, while recognizing the lasting need for comprehensive solid investments that bring in new innovations at much broader regional scale, in the form of the newly innovative mega-projects like HSR, suggests looking closer into specific innovative solutions for railway. The latters promise to work well, in the meantime, to address most urgent needs of developing countries. From that stance, today's needs for new innovative solutions in railway have been clearly specified by ECO's diverse stakeholders. Their prime focus is on the filling-in of the missing links in their currently available infrastructures, logistics and freight throughput to be moved by rail. Their forward-looking focus is eventually on sustainable transport networks (Yoan, 2017).

For practical reasons, the listing of railway-specific innovations solutions (applications) has been reflected in table 2 below. These highlight their close alignment with the present day needs of the ECO countries as strategized in their transport plans and programs.

The outstanding needs of national railway networks of the ECO countries have been multiply discussed at the regional level through high-level meetings of Heads of Railway Authorities of the ECO Member States. Thus, the ECO stakeholders' prime concerns are associated with low 'cargo mobilization'[1] on the key regional railway corridors (Ministerial, 2018). The need for the new innovations solutions to handle infrastructure inefficiencies is through the automated bogie change. The change of bogies is one of the most acute challenges for the regional railway. As such, it has especially been prioritized by stakeholders.

Table 2. Innovations solutions in railways

Types of innovations	Expected Change	Expected Benefits	Efficiency	No.
Green electricity stations	Increase in share of green traction system to 80% by 2025	Save up to 35,000 tons of CO_2 p/y	96 stations in ECO region are used y\y	1.
Hybrid Power Pack	Conversion of rail fleet to hybrid	Benefits of battery-powered and diesel-powered traction system merged into an electrical unit to function both as a motor and a generator	Noise reduction up to 75% and reduction of CO_2 emissions by 20%	2.
Freight wagons with modular frames enabling automated bogie change	Use of flexible flat steel shipment	Multimodality Flexibility Cost effectiveness	1-2% less energy consumption	**3.**
Natural gas powered train	Conversion of trains to methane	Carbone dioxide emissions by 20% by 2025	Replacement of 200 trains will saves up to US$3 mn in fuel costs.	4.
Low maintenance automation trains	Track machines to operate under weather conditions	Additional traffic volumes amount of 23.9 million tones p/y by 2025		5.
Weld traceability across supply chains in the rail sector	Facilitating the recording and transmission of data b/w welding parties	Saves time on Manuka form completion; Provides instant information on each weld	Industry 4. Visibility (via Pandrol Connect)	6.
Robotic installations	Bogie design and production			7.
Advanced truck systems (ATS)	2-pace bogies system	Increase payload; Reduce wheel and track wear	Predicts wheel set conditions; Planned maintenance;	8.
Hydrogen trains	Emits water only	Decarbonized railway	Generation of highly skilled engineering jobs	9.
On-board railway electrical system				10.
Dual system, electricity and diesel autonomous locomotives	Handles both, shunting and lining operations without changing the vehicle	Autonomous steering system controlled by artificial intelligence	Installation of system of sensors, cameras, gyroscopes	11.
On-line marketplace in the railway sector	Specialized platform for buy and sell mobility-related products and services	Fluidity to supply chains of mobility; orders; delivery Covers trains infrastructure depots and stations		12.
Rail Cube Software Solutions	Digital planning, ordering and dispatch.	Standardization across borders.	Comprehensive door-to-door logistics Connection to economic. Areas	13.
Digital railway system				**14**

[1] The ECO specific term - 'cargo mobilization' - has been construed in the present paper as 'railway freight traffic flow'.

Based on the above explanations, this paper singles out among the many new innovations solutions, the following ones: No. 3: Freight wagons with modular frames enabling automated bogie change and No.14: Digital railway system out of 14 reflected in Table 2. The choices have entailed from the first priority issues that have been specified by stakeholders at high level for the ECO.

As with the acknowledging of ever acute need for new innovations solutions in railway, the paper saw it reasonable to define the 'operational efficiency' in individual railway networks of the ECO countries. That would help identify how the efficiency changes with the introduction of new innovations solutions in the regional railway. In so doing, the paper, at onset, developed clear measurements to identify how established are the operational capacities in the individual railway networks of the ECO countries, under the present observation.

1.3 Defining ECO railway network's operational efficiency

The ECO Railway Network (ERN) was established in 2012 (Tramboulas, 2012). It has five key railway corridors that have, in the ECO context, been named as 'routes'. Those are, as follows:

Route No.1 (6543km)

Türkiye

(Bulgaria border)-Kapikule/(Greece border)-Uzunkopru-Istanbul (European side)-Ferry segment (tunnel under construction)-Istanbul (Asian side)-Izmit-Bilecik-Eskisehir-Ankara-Kayseri-Bostankaya-MalatyaElazig-Mus-Tatvan-Ferry Lake Van (new alignment planned)-Van Kapikoy-(border with Iran)

Iran

(Border with Türkiye)-Razi-Sufiyan- Tabriz-(Maraqeh)-Miyaneh (under construction) Zanjan-Qazvin-Aprin (near Tehran)-Mohammadiyeh Kashan-Yazd-Bafq-Kerman-Bam-Zahedan-(gauge change to 1676 mm)-Mirjaveh-(border with Pakistan) Pakistan (border with Iran)-Taftan – Nok Kundi-Dalbandin-Ahmad Wal-SpezandKolpur-Abi Gum-Sibi-Jacob Abad-Rohri-Samasatta-Multan-KhawalFaisal Abad-Wazirabad-Lalamusa-Rawalpindi-Islamabad

Map 1: Map of Route 1

Route No 2 (5626km)

Türkiye

(Bulgaria border)-Kapikule/(Greece border)-Uzunkopru-Istanbul (European side)-Ferry segment (tunnel under construction)-Istanbul (Asian side)-Izmit-Bilecik-Eskisehir-Ankara-Kayseri-Bostankaya-MalatyaElazig-Mus-Tatvan-Ferry Lake Van (new alignment planned)-Van Kapikoy-(border with Iran)

Iran

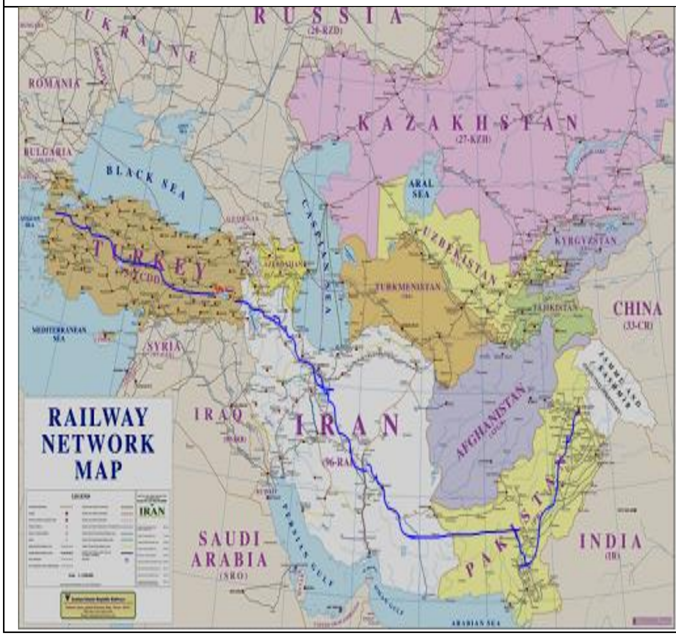
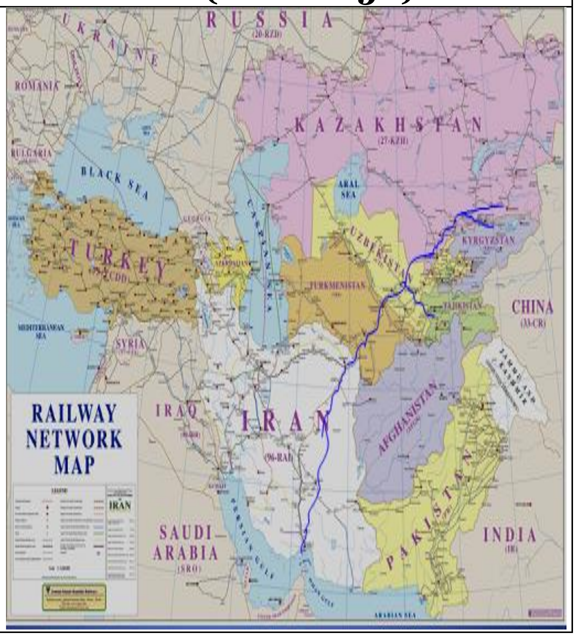
(border with Türkiye)-Razi-Sufiyan- Tabriz-(Maraqeh)-Miyaneh (under construction)-Zanjan-Qazvin-Aprin (near Tehran)-Semnan-Neyshabur-Sarakhs-(border with Turkmenistan)

Turkmenistan

(border with Iran)-(gauge change to 1520mm)-Serakhs-Yoloten-Mary-Turkmenabad-Farab- (border with Uzbekistan) Uzbekistan (border with Turkmenistan)-Khojadavlet-(Bukhara)-Navoi-SamarkandJizzakh-Khavast-Tashkent-(border with Kazakhstan)

Kazakhstan

(border with Uzbekistan)-Saryagash-Arys-Shymkent-Lugovaya-BirlikAlmaty-Aktogai-Dostyk-(border with China**)** towards Alashankou/Urumchi

Istanbul-Almaty (ECORail2A)	**Bandar Abbas – Almaty (ECORail5B)**
	

Map 2: Map of Route 2

Route No. 3 (338km)

Main route connected to branches	Branches
Azerbaijan [railway gauge 1520mm] (border with Russia)-[standard gauge]-Yalama-Sumgait-Baku-Astara-(border with Iran) **Iran** (border with Azerbaijan)-Astara-(under construction)-Qazvin-Karaj-Tehran-Qom-Yazd-Bafq-Sirjan-Bandar e Abbas **Branches: ECO RAIL 3-B-A (CASPIAN SEA, AZERBAIJAN, IRAN)** [Construction completed: Qazvin-Rasht and Bandar e Anzali]-ferry segment to Baku exists. (Azerbaijan) **ECO RAIL 3-B-B (CASPIAN SEA, KAZAKHSTAN, IRAN)** [under construction: Rasht-Astara and Bandar e Anzali]-missing ferry segment to Aktau (Kazakhstan)	**ECO RAIL 3-B-C (CASPIAN SEA, TURKMENISTAN, IRAN)** [under development: Qazvin-Rasht-Bandar e Anzali]-ferry segment to Turkmenbashi (Turkmenistan) **ECO RAIL 3-B-D (IRAN)** Qom-Arak-Ahvaz-Bandar e Emam Khomeini **ECO RAIL 3-B-E (IRAN)** Bafq-Kerman-Zahedan-(under construction) Chabahar

Map 3: Map of Route 3

Route No. 4 (924km)

Kazakhstan

(border with Russia)-Zaisan-Aktobe-Kandagach-(under construction)-Makat-Beineu-Aktau-Uzen (under construction)-(border with Turkmenistan)

Turkmenistan

Under construction: (border with Kazakhstan)-Bereket-Godurolum-(border with Iran)

Iran

(under construction)-(border with Turkmenistan)- [railway gauge 1536mm]-new line to Incheh-Boroon-Gorgan-new line Shahrud-Neyshabur-Torbat e Heydarieh-Bafq-Sirjan-Bandar e Abbas

Map 4: Map of Route 4

Route No 5. (est. 1,200km)

Kyrgyzstan

New line: (border with Tajikistan)-Sary Tash-Irkeshtam-(border with China) towards Kashgar (Kashi)

Tajikistan

[under construction: (border with Afghanistan)-Nijnii Pyanj-DustiKalkhaz Abad]-Kurgan Tube-Kulyab-(new line)-Yavan-(under construction)-Vahdat-(new line)-Karamyk-(border with Kyrgyzstan)

Afghanistan

(border with Iran)-under construction until Herat-[new line: Kusk-Kalainau-Meymaneh-Andkoy-Sheberghan-Mazar e Sharif]-[under construction: Baghlan-Kunduz-Sherkhan Bandar-(border with Tajikistan)

Iran

(border with Türkiye)-Razi-Sufiyan- Tabriz-(Maraqeh)-Miyaneh (under construction)-Zanjan-Qazvin-Aprin (near Tehran)-Semnan-Neyshabur-Sarakhs-(border with Turkmenistan)-Ma’dan e Sangan-(under construction until border with Afghanistan)

Map 5: Map of Route 5

The above-described five key railway routes of ECO are in ownership of the key nodes in each (ECO, 17-18 May 2017). The following table illustrates the number of nodes within each of the five of ECO's key railway routes, dubbed after the names of the country they belong to.

Table 3: ERN key routes, nodes, rail-based segments, innovations-paired segments

No.	Nodes	ECO Railway Routes	ECO-specific names o railway routes	Indication of railway segments that are connected to nodes
1	Zahedan-Taftan	No. 1	ITI	z
2	Serakhs	No. 2	ECORail2A-5B	s
3	Astara	No. 3	Qazvin-Rasht-Astara	a
4	Incheh-Borun	No. 4	KTI	i
5	Turgundi	No. 5	KTAI	t

The following definitions in the paper have been used to employ the key measurements for the analyses to describe major parameters of such indicators:

Table 4: Definitions

ETNE – ECO Transport Network Efficiency ERNE- ECO Railway Network Efficiency ETNE, T= (N, A); ERNE = ε; I – Innovations meaning the new innovations solutions such as applications that are specific for ECO; N – set of the ERN's nodes consisting of I_n elements;	A – set of the ERN railway lines with n_a elements; W – set of Origin-Destination (OD) pairs the ERN nodes with n_w elements; K_n – set of patterns connecting the OD pairs; q_w – demand for the OD pairs.

In each node the number of stations varies: the KTI (Map 4: Route 4.) has only 12 stations along the entire corridor whereas the Istanbul-Almaty & Almaty-Bandar Abbas railway corridor has 37 stations and ITI railway corridor has 48 stations. The analysis under this paper focuses on the consideration of railway freight traffic flow (x_z), which in the context of the present analysis stands for 'cargo mobilization': (x_z). The analysis also focuses on the new innovations solutions termed under the present analysis as the 'Innovations': ($I_z(x_z)$. The latter has been examined from the point of view of how it may impact railway freight traffic flow i.e. 'cargo mobilization' (Report of the 13th Meeting of Heads of Railway Authorities of the ECO Member States, 2017). As mentioned earlier in the paper, the ECO stakeholders have particularly been deeply concerned about 'cargo mobilization' by rail, which, in their opinion, has been low (The 9th Meeting on ITI Container Train, 2017). Likewise, (x) has been examined through the prism of how it be impacted by (I), both being one of the major components of the ERN, under this paper. The term – 'Innovations' – has been used in the analysis to indicate a set of the new innovations solutions (applications) that are specific for ECO (for details pl. see Table 4).

With the objective of exploring how the new innovations solutions will impact the functioning of the ERN, the paper has deployed the two component non-parametric analysis (Sarmento, Renneboog, &Verga Matos, 2017) by using formula of defining the efficiency of the railway network: $\varepsilon = \varepsilon(R, q) = \frac{1}{n_A} \sum_{z \epsilon A} \frac{x_z}{m_z}$;

In the context of the ECO, R indicates the regional railway network. Thus, the analysis method admitted that the function of the Innovations is, in fact, its cost value. The latter has been admitted under the assumption that prior to implementing any new innovation into practical life of any given railway network in the ECO region, the stakeholders in the member countries will first look into how feasible the innovation may turn out to be, in terms of its cost. Thus, the Innovations I_z (x_z) in this paper has been reflected through the following equation:

$$I_z = \left[1 + \alpha \frac{x^z}{c^z} \beta\right]; \tag{1}$$

In equation (1), c_z- capacity of railway segment z;

α and β – the Innovations cost's parameters that were set as constant at: α=0.15; β=4;

The latter parameters evolved from the regional average score on infrastructure and logistics, which when adjusted to the realities of the ERN resulted in the above numeric values that have been taken as constant for computations under the present analysis.

The conditions for indicator variable σ_k^a have been set as:

$$\sigma_k^a = \begin{cases} 1 \text{ if segment } \alpha \text{ is on the path } K; \\ 0 \text{ otherwise;} \end{cases}$$

In equation (5) *m* stands for railway cargo mobilization cost, which has been admitted by stakeholders to be low on rail-based segments (RPC, 14-15 Deecember 2017);

Railway cargo mobilization pattern on a given rail-based segment has been set at:

$$\text{Min } \sum(x) = \sum_{\alpha \in A} \int_0^{x_a} I_a \ (y)dy; \tag{2}$$

$$\text{s.t.d. } \sum_{mk}^{w} = qW, \forall\, W \in W; \tag{3}$$

$$x_a = \sum_{w \in W} \sum_{k \in K} mk\, \sigma_k^a \,, Y_q \in A\,; \tag{4}$$

$$m_k^w \geq 0, \ \ \forall \mathrm{w} \in \mathrm{W}, \ \ \mathrm{Y_k} \in \mathrm{K_w}\,; \tag{5}$$

2. Defining the role of the innovations in the ERT and ERN

The paper recognizes the need for the new innovations solutions as seen in this paper to minimize its cost in order to be feasible for the ECO stakeholders to implement innovations in their respective railway networks. For that, the paper finds the efficiency of the overall ECO Transport Network (ERTE), indicated as 'E'. Such step is needed because the ECO Railway Network (ERN) is, in fact, part of the ECO Transport Network (ETN) (Shimoya, 2016). The formula deployed for computing ERTE has been, as follows:

$$E = E(T) = \frac{1}{n(n-1)} \sum_{c \neq s,z} \frac{1}{d_{s,z}}; \tag{6}$$

In formula (6) E is the efficiency of ETN;

n – number of elements in ETN;

d – demand for cargo mobilization in ETN;

z, s – railway segments within ERN.

The paper first identifies the levels of prominence of the ERTE components' values. The latters are to be used to then define the impact of the innovations on the railway traffic flow i.e. cargo mobilization. In the formulaic context, ERTE is 'T' Thus, T and t∊T have been presented, as follows:

$$p_{\mathrm{t}}(t) = \frac{\Delta \mathcal{E}}{\mathcal{E}} = \frac{\mathcal{E}\,(T,d) - \mathrm{t}(T-t,d)}{\mathrm{t}\;(\mathrm{t,d})}; \tag{7}$$

In equation (7) $p_{\varepsilon\,(t)}$ is the prominence value of component t based on the ERN's efficiency ε;

T-t represents the status of the ETNE indicating instances when it functions without the innovations solutions embedded in component *g* of ETN (T);

The ranking of prominence values has been fulfilled in the descending order with the upper bound having been set at '1' following the WDI indexing.

The prominence value of the ERN's component t∊T, based on the ETN's overall efficiency E, has been formulaically employed, as follows:

$$p_E(t) = \frac{\Delta E}{\mathrm{E}} = \frac{E\,(T,d) - E(T-t,d)}{\mathrm{E}\;(\mathrm{T,d})}; \tag{8}$$

The paper while assuming that the rail-based segment marked as 'with the innovations solutions introduced', presented the cost function of the new innovations solutions, as follows:

$$p1_{a\,(x_z)}) = 10[(1 + 0.15\left(\frac{x_z}{4}\right)^4; \tag{9}$$

$$p1_{s\,(x_s)}) = 15[(1 + 0.15\left(\frac{x_s}{6}\right)^4; \tag{10}$$

$$p1_{a\,(x_a)}) = 12[(1 + 0.15\left(\frac{x_a}{3}\right)^4; \tag{11}$$

$$p1_{d\,(x_i)}) = 15[(1 + 0.15\left(\frac{x_i}{10}\right)^4; \tag{12}$$

$$p1_{t\,(x_t)}) = 20[(1 + 0.15\left(\frac{x_t}{8}\right)^4; \tag{13}$$

In the above equations, p1 (x_t) is the cost value prominence of component *t* based on the ERN's efficiency ε;

By using the generalized gradient projection method, which is commonly applied in analyses when it concerns the differing levels of items under an observation, the paper computed the following numeric values:

$$\overline{\mathrm{x}} = \bar{\mathrm{x}}_{z,}\bar{\mathrm{x}}_{s,}\bar{\mathrm{x}}_{a,}\bar{\mathrm{x}}_{i,}\bar{\mathrm{x}}_{t}\,\} = \{5.7728,\ 4.2272,\ 6.1893,\ 5.4165\};$$

Based on the above-described equations and *x*, the paper computed the ETN's efficiency i.e. ERTE, as follows: E =0.0195. It also computed the ERN's efficiency (ERNE), as follows: Ɛ=0.2688. Based on the resulting numeric values, the total cost value of new innovations solutions has equaled to: 120.5456.

Stemming from the structuring of the ECO Railway Network (ERN), the below table illustrates the ERN's railway nodes and rail segments.

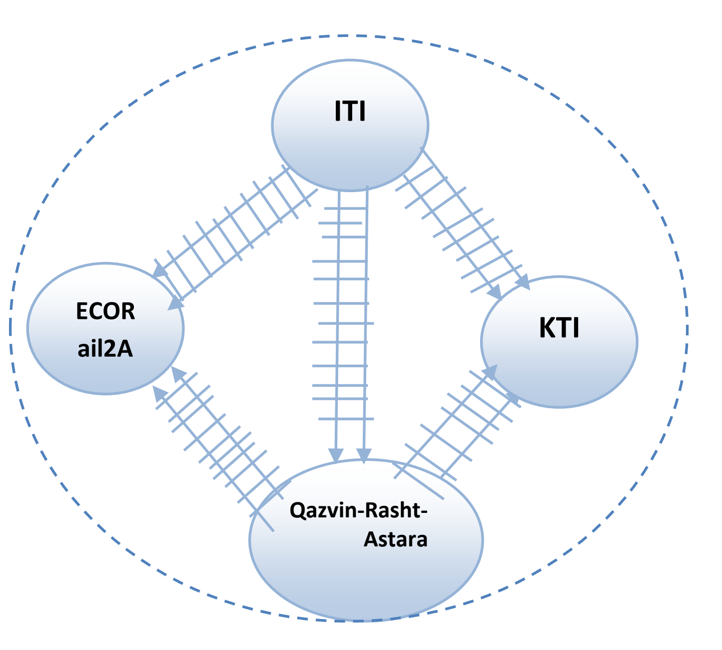
Table 5: The ERN nodes and ERN rail-based segments

No.	ECO Railway Network nodes	ECO Railway Network routes' segments	Numbering of rail-based nodes in scheme 1
1	Zahedan-Taftan	Z	No. 1
2	Serakhs	S	No.2
3	Astara	A	No.3
4	Incheh-Borun	I	No.4
5	Turgundi	T	No.5

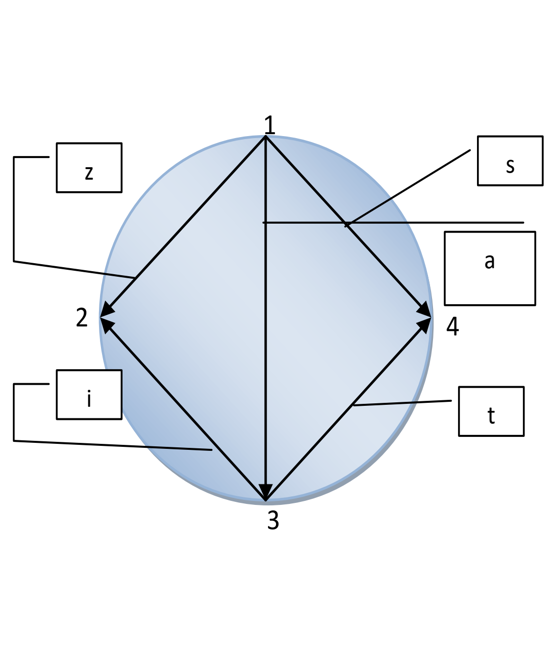
The paper also observed the dynamics in the changes in the ERNE depending on whether its rail-based segments were paired within the corresponding the OD pairs connecting the latters to the following conditions: (i) 'with' or (ii) 'without' the innovations solutions, to be observed under this analysis. For better clarity, the analysis makes a reference to the assumed act of the pairing of the new innovations solutions via the OD pairs. In this the term: "with" has been applied. In other works, the role of the OD pairs in this observation is that they indicate the paring of a given rail-based segment's link 'with' the new innovations and those instances when the same rail-based segment's link is 'without' the innovations. The assumption taken in relation to the above-described pairing stems from the theory that the efficiency of any given transport network is computed based on a relative drop of network efficiency value after it is completely blocked or failed within the network (Dalmo, 2019). Thus, the analysis refers to the assumed absence of the paring of new innovations solutions on a given railway segment of the ERN. In this, the absence of new innovations solutions was indicated by term: "without". Graphically, the ERN's railway nodes and their corresponding rail-based segments as linked to the OD pairs following succession of their vector directions on which demand q was ensured along the pairs (diagram 1 and scheme 1).

ECO railway nodes and rail-based segments within ERN

Diagram 1.



Scheme 1.



In exploring the efficiency changes, Figure 1 illustrates that the ETN's efficiency (*E)* and the ERN's efficiency (ε) do change given the railway cargo mobilization at demand q_{12} depending on whether the railway segment z is 'with' or is 'without' the innovations solutions.

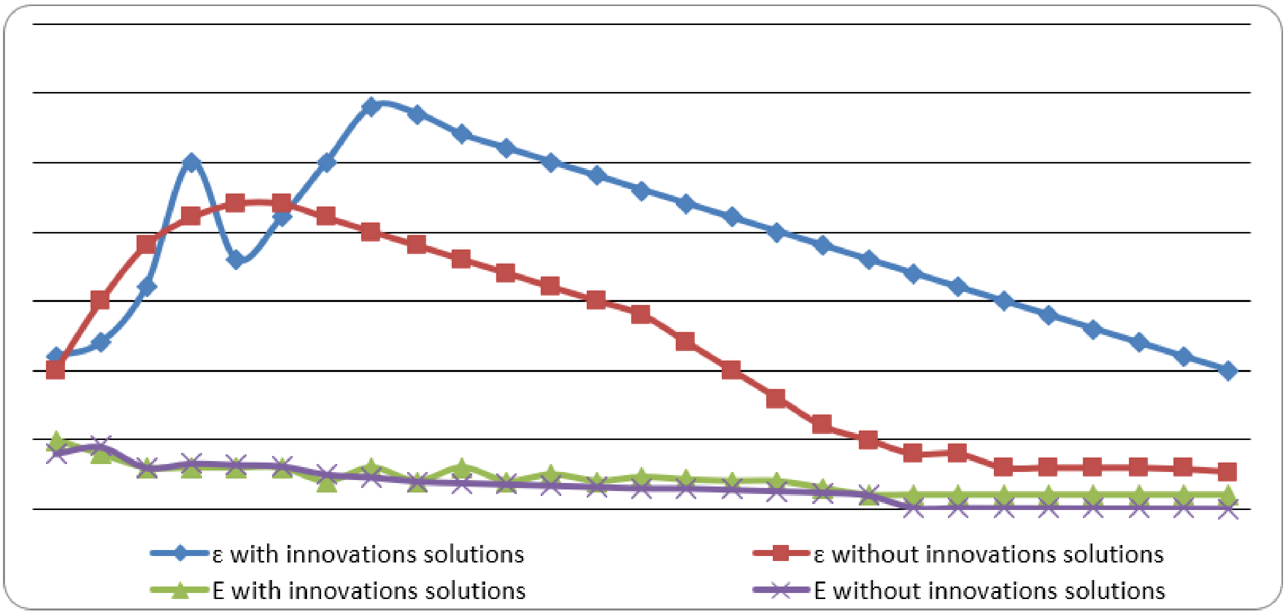


Figure 1: Change in efficiency of ERT and ERN 'with' and 'without' innovations solutions at a lower demand

Figure 2 reveals that the changes in efficiency Ɛ of the ERN and *E* of the ETN stem from the pairing of the rail-based segment *s* with the new innovations solutions through the OD pairs. The latters also occur in their dependence on the conditions of 'with' and 'without' the pairing of the new innovations solutions to the corresponding rail-based segments at a given cargo mobilization demand: q_{14}.

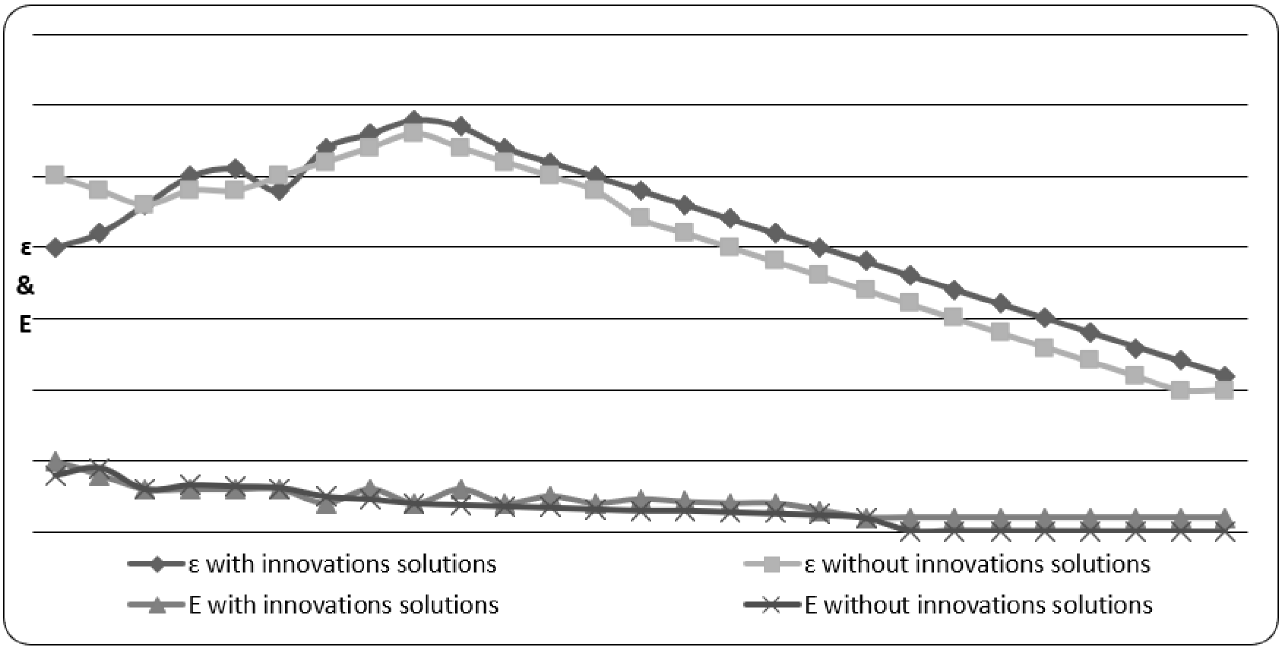


Figure 2: Efficiency of ETN and ERN under conditions of paring 'with' and 'without' innovations solutions at higher demand

Based on the above observations, efficiency *E* of the ERN decreases regardless of whether it has been paired 'with' or 'without' the new innovations solutions on rail-based segments *z* and *s*. The value of *E* 'with' the innovations solutions on rail-based segments turned out to be always larger compared to when it is 'without' the innovations solution on the corresponding rail-based segments.

3. Findings

Being supported by the above-described observations, the paper sums up the two key findings:

(1) The change in the ERN's efficiency i.e. ERNE describes the status of the function of the ERN's infrastructure and cargo mobilization.

(2) When the overall ETN does change, basing such changes on its railway cargo mobilization, in the ERN's real-time infrastructure, there is more than one prominent spot of which the quantity directly relates to the number of railway paths ensuring installation of new railway innovations solutions on the rail-based segments between the changing OD pairs as identified in scheme 1 and diagram 1.

3.1 Innovations and efficiency of railway segments 'with' and 'without the innovations solutions'

Figure 3 below reflects the efficiency on the ERN's rail-based segments 'with' and 'without' new innovations solutions. It also shows the cost function of the innovations when paired 'with' new innovations solutions, which is not high, compared to when it were to incur in the framework of the mega projects requiring massively huge capital investments.

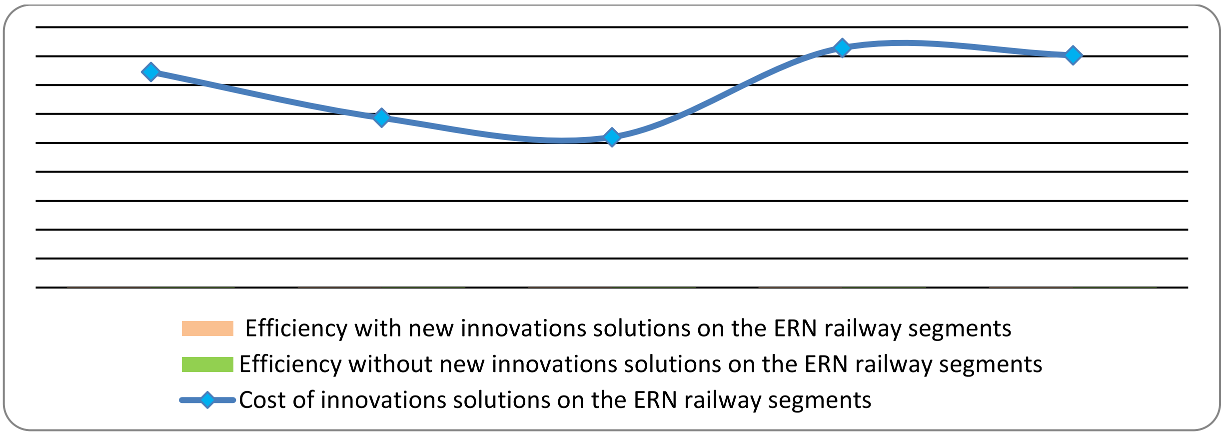


Figure 3: Innovations cost and efficiency of ERN 'with' and 'without' innovations solutions

Overall, the figure above reflects the cost function of the innovations. It also shows how efficiency of the ERN changes with the introducing of the new innovations solutions compared to the efficiency but without its pairing with the new innovations solutions in instances when the latters fail to be introduced.

The critical components of the ERN's efficiency i.e. ERNE can be seen based on the prominence of values of ERNE's major components. In this visibility, the component indicating the prominence of a value, in the descending order, may be admitted as the first one in the ranking (Lorenzo, 2013). If to follow the analysis under the A, B, and C categorization, the highest 20% of ERNE's components can be recognized as 'critical' and those falling within the range of 20%-50% as 'important'. The rest may be viewed as 'common' values.

The findings of this section are such that ERNE's components like ERN's nodes and its rail-based segments, even under conditions of a non-integrated network, could be used to further identify critical components that require the attention of stakeholders in any given railway network. Under *ceteris paribus* in the context of this paper, the fixed-demand has been set at moderate as the characteristic of the comprehensive transportation network. That has been assumed as constant.

3.2 Conclusions on technological implications of new innovations

The paper, when considering the technological implications for the regional railway, has revealed the operational efficiency of the ECO Railway Network (ERN). Not only that the paper computed the impact of the innovations on railway efficiency but also showed how demand in cargo mobilization changes upon introducing the new innovations solutions in railway networks of the ECO countries. It also revealed that the new innovations solutions and cargo mobilization are the most prominent critical components of the ERN's efficiency. For more, the new innovations solutions and cargo mobilization are the functions of the ECO Transport Network (ETN). Efficiency and ERN's components' prominence values are, in turn, the functions of 'cargo infrastructure' and infrastructure and, for that matter, it is universally admitted that new innovations are part of the infrastructure in transport.

Building further on the latter observations, future research may describe how railway cargo mobilization, new innovations, innovations-focused skill and railway infrastructure would affect progressive railway operations. Most importantly, this paper revealed that the new innovations are one of critical components of the ERN's functioning because it brings the increasing efficiency into the ECO's regional railway performance. Such findings are important for the effective coordination amongst countries at regional level. The latter could be used in guidelining for the purposes of: (i) cargo mobilization on any given railway network; (ii) infrastructure reconstruction/rehabilitation, (iii) maintenance, and (iv) informed planning and decision-making. The paper also points at productivity of the ERN from the point of view of performance in individual countries' railway modes of the ECO transport.

3. 3 Technical Implications: Interoperability methods

Interoperability is critical for success of railway operations. Most often than not the interoperability does come along with new innovations in railway. Technical implications entail managerial efficiency. For the betterment of the latter, new innovation coordination and guidelines would be needed (Edquist, 2019). Stemming from the operational efficiency described in earlier sections of this paper, the interoperability will be examined in this section in relation to how it could work in the context of the ERN. For this, the paper deploys the operational criterion.

Operational criterion

It is not unusual in ECO for one railroad's locomotives to operate on one another's tracks. In such practices, the tenant locomotives are linked to the host railway control systems. Over the past, container trains along ECO's rail corridors were granted 'green light' for pass-through in test-utilizing the formal channels of communication. As with the introduction of commercialization on regional railway corridors and new technology proposed by ECO's Regional ICT Development Strategy (ICT Ministerial, 2017), which was adopted in December 2017 in Baku during the 2nd Ministerial Meeting on ICT, the model of interoperability has to change. The change has also been necessitated by the inter-regional developments, which followed the concept of the interoperability to embrace a wider perspective "not just technical specifications but an intra-and-inter-regional policy to enhance ICT-related industries while serving as a prerequisite for fully functioning of the Information Society" (Branislav, 2018; EU, 2004, p.7). Based on the above, the model will be structured to meet the following targets: (i) to interoperate across distributed networks; (ii) to accommodate multiple communication system designs; (iii) to support radio interchangeability on board and locomotive, (iv) to support varying deployment timelines, and (v) integrate the above-indicated targets under the comprehensive work plan of the CME on every of ECO's railway corridor.

As required under this model of interoperability on ECO's railway corridors, each railway segment will have to install the train control system (TCS) wayside, back office, locomotive hardware and ensure comprehensive capacity-building training. The installation of TCS and wayside location stations has been envisaged in Article 9 (f) of the ECO's Transit Transport Framework Agreement (TTFA) whereas the installation of back offices and related hardware/software are aligned with Article 8 as well as Article 11 of the TTFA.

Given the new challenges reflected in ECO's strategy on ICT, immediate steps to initiate the model of interoperability on railway corridors will include the following practical actions/measures:

(1) Undertake inspections of the current status of installations along the distance of a selected railway corridor;

(2) Install the train control system equipment on the locomotives and railroad facilities;

(3) Develop, produce, and deploy radio system designed for data transmission of train control system messages at all base stations and trackside locations and on locomotives;

(4) Complete signal replacement, including upgrades to train control systems at all stations along the ECO railway corridors in compliance with ECO Map of Railways;

(5) Develop back office systems and upgrade and integrate dispatching software to include the data required for the train control systems.

(6) Test the integration of all components the system through test runs of container trains.

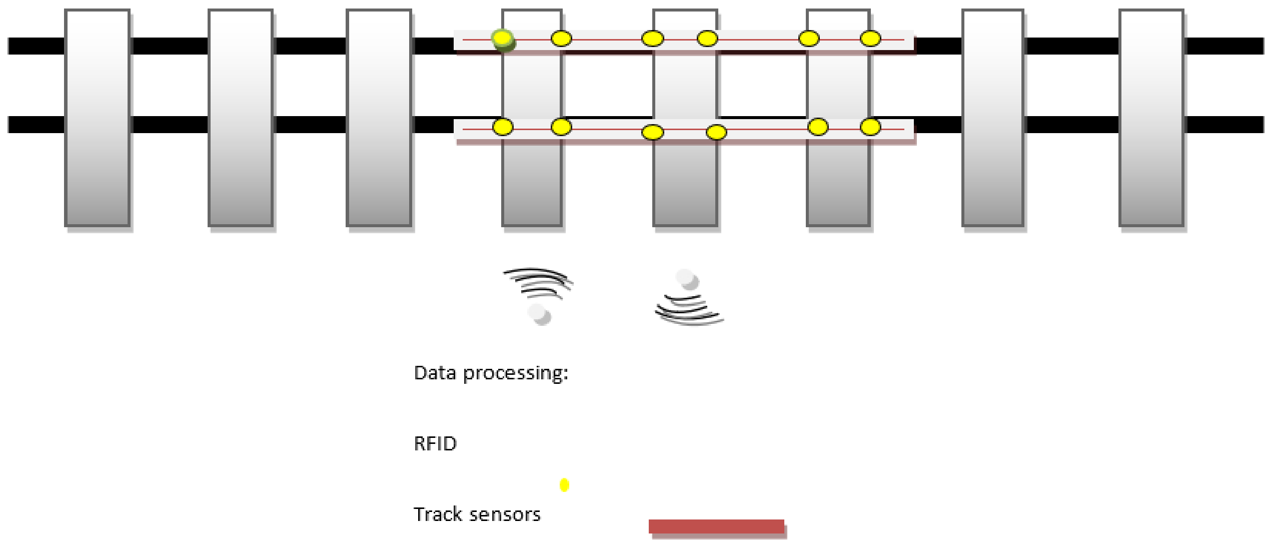
(7) Test interoperability amongst en-route countries railway networks in utilizing the system.

The path to achieving interoperable sustainable operations on the regional railway corridors have been defined to be through optimization (ECO-ITU Joint Study on ICT, 2017); (ECO Vision 2025). By optimization in railway, this paper implies the method of making the system as perfect, cost-effective, and qualified as possible considering the existing operational constrains and conditions (Hayat, 2017; Ali Zamani, 2011, p.7). The optimization will require installment of the automated supervisory control and data acquisition system (ASCADA). In some of the en-route countries along ECO's key railway corridors, the prototype ASCADA system has already been installed (para-76, Report of the 9th Ministerial; Meetings, 2018); in some others, notably, Turkmenistan ASYCUDA is being installed, in others, including Tajikistan, Kyrgyzstan and Afghanistan it is under consideration. Bearing in mind that the existing railway corridors run through territories of the en-route countries that have been equipped with ASCADA or its prototypes, the following steps have been identified as first immediate for the development of the interoperability model. Most of en-route countries have equipped their locomotive trains with the automated train control systems (TCS) since the serial production of those follow the new technology standards in wagon and loco production. Providing for the central dispatch system of railway corridors will be the core issue to be resolved by the CME, which has been envisaged on the KTI railway corridor as a point of a single window and a single contract (as described in the introduction section).

Based on the above-described arrangements, the following summary of the actions/measures towards the optimization for operability and sustainability have been identified by the paper in the following order of sequence:

1. Automated supervisory control and data acquisition system
2. Automated train control system
3. Central dispatch system

The scheme of optimization with the objective of achieving sustainable and interoperable railway operations is presented below, as follows:

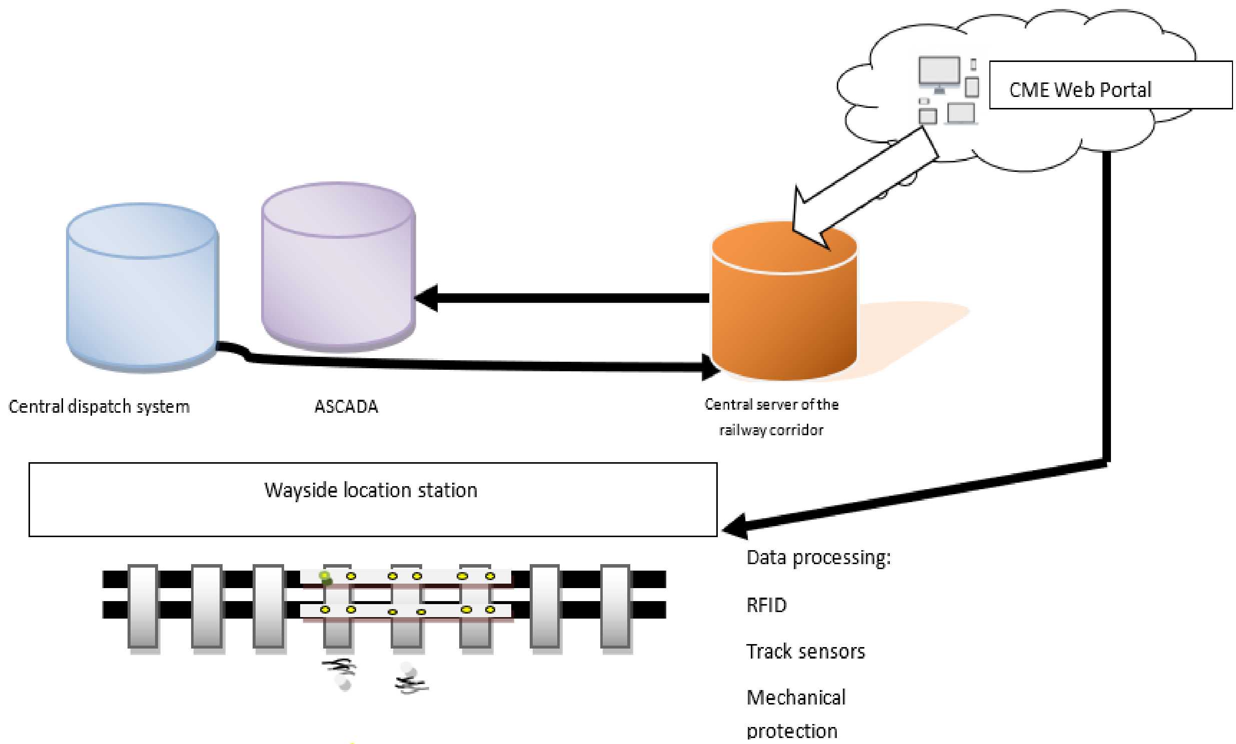


Scheme 1: Optimization scheme to achieve sustainable/interoperable railway operations in ECO

The actions/measures embedded in the optimization scheme have to be integrated under the ECO railway corridors' management. In that regard, the common CME portal will be linked through central server to: (i) automated supervisory control and data acquisition system, (ii) central dispatch system, (iii) wayside location station to read the data of the automated train control systems. The KTI (Map 4: Route 4.) has only 12 stations along the entire corridor whereas the Istanbul-Almaty & Almaty-Bandar Abbas railway corridor has 37 stations and ITI railway corridor has 48 stations. Therefore, the installation of wayside location stations will be on 97 stations at the regional level. The train-based control systems will have to be installed on the ITI railway route, in Pakistan's segment as the locomotives in this segment are largely outdated.

The configuration of the monitoring platform within the interface of the CME's web portal to be set up may be discussed and defined by the CME's participating parties depending on the design propensities of the involved en-route countries. The platform will function as a SIMobility tool of business-to-business communications enabling the integration of mobility services of various providers (such as road trucks connecting their freight to rail) into a "one window, one-stop portfolio" for the users in railway transport mode (Jarasueniene, 2017; Pieriegud, 2018) p.39.

In the meantime, the holistic scheme of the integration of the CME internal control system with the components of the optimization scheme may be presented as follows:



Scheme 2: Integration of internal systems of CME with the optimization scheme components

Systemic criterion

Under this section, the systemic criterion accounts for frameworking the structure of systems involved in railway operation to realize the desired interoperability from the regulatory perspective (Jayani R.P., 2018). Interoperability in railways does not only require technical, operational, and digital interoperability but it "also requires interoperability of physical and rules-based layers across vast geographies" (WB, 2010); (WEF, 2018) p.14. In this regard, the ECO's legal guidelining framework – TTFA – defines rail transport, primarily, from the point of view of transit railway transport. The TTFA in its Part VI, Article

23 designates the central role to the railway interchange stations in railway transit. The legal framework envisages the inter-railway agreements where the rules and norms for railway transit could be specified for railway corridor operations. Based on this regulation, the interoperability model should be embedded in the inter-railway agreements, including all type agreements and project contracts amongst en-route countries. The practices of such arrangements may include memoranda of understanding, letters of intent or as in the case with the KTI project – memorandum of agreement where the task of creating the CME has been reflected in the work plan of project activities. Based on ECO's legal regulatory system's norms, the targets in developing the model of interoperability for railway corridors will be as follows: (i) to incorporate the interoperability model in the work plan of the project on the railway corridor; (ii) define its characteristics in the description of project activities, and (iii) ensure for the inter-railway arrangement. The technical norms and regulations in this process will be aligned with those of the (iv) Agreement on International Passenger Traffic by Rail (SMPS), (v) Agreement on International Carriage of Goods (SMGS), (vi) COTIF/CIM, and (vii) CIV, and also, within the framework of (viii) CAREC and (ix) UIC. Such norms have been prescribed in Article 23 paras-4 and 5 of the TTFA. Table 6 below reflects the 12 actions in regulatory space to achieve sustainable interoperability.

The systemic interoperability framework reflecting the interoperability on normative regulations amongst the ECO and international organizations specializing in railways envisages the CME to be in the framework of inter-railway agreements amongst the en-route countries of the regional railway corridors. Those legal instruments may be in the forms of memoranda, memoranda of agreements, letters of intent, contracts, project agreements as practices-based empirical evidences revealed in the ECO region (pl. see Figure 4 below).

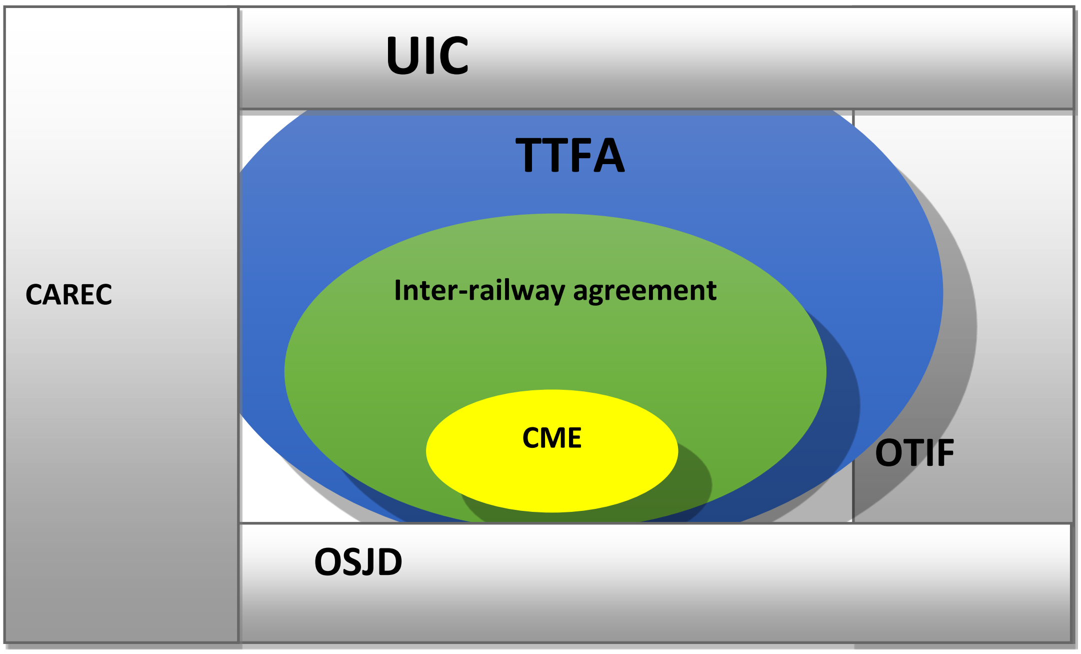


Figure 4: Systemic framework of the interoperability model

Table 6: Regulatory actions needed to comply with in achieving the interoperability on ECO railway routes

No	Regulation-based actions	Article	Responsible	Specified
1	To grant the TTFA member the necessary transport facilities through its territory	No. 4	Contracting Party	TTFA, Annexes
	To facilitate movement of goods through respective territories of the Contracting Parties and provide all necessary facilities for transit transport.	No.2		
	To adopt the prescribed railway transit route.			Annexure-I.
2	To notify the TTCC about additional routes and their characteristics	No. 6	Railway Authority	Annexes II, III
3	To provide adequate facilities and related installations for road, rail and inland navigation and multimodal transport.	No. 8	Contracting Parties	
4	• To establish posts at designated frontier points with control areas. • To ensure adequate manpower resources be available for speedy completion of frontier formalities. • To coordinate working hours of adjacent frontier posts. • To provide reliable mail and telecommunication services. • To facilitate speedy and efficient transit of goods. • To adopt a uniform set of consignment notes/way bills.	No. 9	Contracting Parties	
5	To ensure safety of traffic & ecological protection along ECO's transit routes.	No. 10	Institutional	
6	To establish relevant offices in accordance with domestic legislation.	No. 11	Ministry of transport	
7	To ensure conformity to technical requirements on a transport vehicle dimensions, maximum total weight/axle load and other parameters.	No.17	Contracting Party	Annex IV.
8	To establish border stations and interchange stations for transit transport.	No. 23	Contracting Party	Annex-I
9	To arrange inter-railway agreements between the TTFA members.	No. 24	Railway Authorities	
10	To establish a Customs Transit System for cargo & means of transport to facilitate the movement of goods in the TTFA members' territories.	No. 28		
11	To notify the TTFA members of any additional requirement or modification in the prescribed documentation/procedures to be introduced in regard to traffic in transit.	No. 31		
12	Institute a basic documentation agreement with the TTFA members to facilitate transit.	No. 33	Railway Authority	Annexure VII

The systemic normative ground of actions designed to support the implementation of the interoperability model on railway operations on ECO's key rail-based corridors from the regulatory perspective may be sourced from Table above, which reflects the main regulatory prescriptions relating to railway operations in ECO.

Capacities-driven criterion

This criterion defines the expected capacities of participating railway networks and their measurable performances required to achieve the defined targets of the interoperability within ERN. The railway networks' performances of en-route countries are varied. That is because the share of rail transport in the respective transport sectors varies. Performances largely depend on the operating length of railways in the en-route countries where that of Kazakhstan is currently 15,529 km and, by contrast, those of Kyrgyzstan and Tajikistan are 420km and 651km. At country level, the 2018 logistics performance, including by rail, has been modest. According to the UN logistics performance index, Türkiye and Iran have been ranked 47th and 64th amongst world's top 50 of the overall 160 countries rated in 2018 as in Table 7.

Table 7: 2018 ECO countries' logistics performance ranking according to UN index

Country	Year	LPI Rank	Customs	Infrastructure	Int. shipments	Logistics competence	Tracking/Tracing	Timeliness
Türkiye	**2018**	47	58	33	53	51	42	44
Iran	**2018**	64	71	63	79	62	85	60
Kazakhstan	**2018**	71	65	81	84	90	83	50
Uzbekistan	**2018**	99	140	77	120	88	90	91
Kyrgyzstan	**2018**	108	55	103	138	114	99	106
Pakistan	**2018**	122	139	121	97	89	136	136
Turkmenistan	**2018**	126	111	117	136	120	107	130
Tajikistan	**2018**	134	150	127	133	116	131	104
Afghanistan	**2018**	160	158	158	152	158	159	153

The deployment of human resources in railway transport in ECO countries depends on the efficiency in this sub-sector. While involvement of high technology in it brings in higher efficiency in railway operations, professional maturity of railway involved personnel depends on the various cognitive approaches that the countries take in this regard (PMI, 2013, p.143). Thus, in Kazakhstan the maturity management model has been introduced at national, regional, and local administration levels based on one of the three principles of public service, which is meritocracy (ACSAA, 2017). Therefore, professional excellence, including in railway subsector is handled at all-country level thereby enabling a comprehensive cognitive approach.

Railway proficiency in Türkiye is being handled at corporate level within the corporate management maturity structure of mega projects on rail transport. A simple solution in this area could be the unified organizational maturity model (Sohail, 2005, p. 3). However, not all ECO countries have installed the similar railway management maturity models. In this regard, the space for prospective improvements in the interoperability model under this paper turns out to be significant.

The targets to pursue along this path may include the following seven actions/measures: (1) introducing the railway management maturity model in ECO countries; (2) organizing a series of short-term[2] comprehensive training programs/courses on the railway management maturity model; (3) establishing the ECO region-specific set of criteria of excellence in the area of railway transport performance; (4) organizing for cost control for interoperability; (5) organizing for the central dispatch center; (6) organizing for the train control systems in en-route countries; (7) organizing for the integration on ECO's railway corridors. At the back of the seven targets for a comprehensive short-term capacity building in en-route countries' railways, the capacities-driven criterion of the cognitive dimension in the interoperability model of ECO's railway corridors is suggesting the following nine actions/measures, as structured in Figure 5:

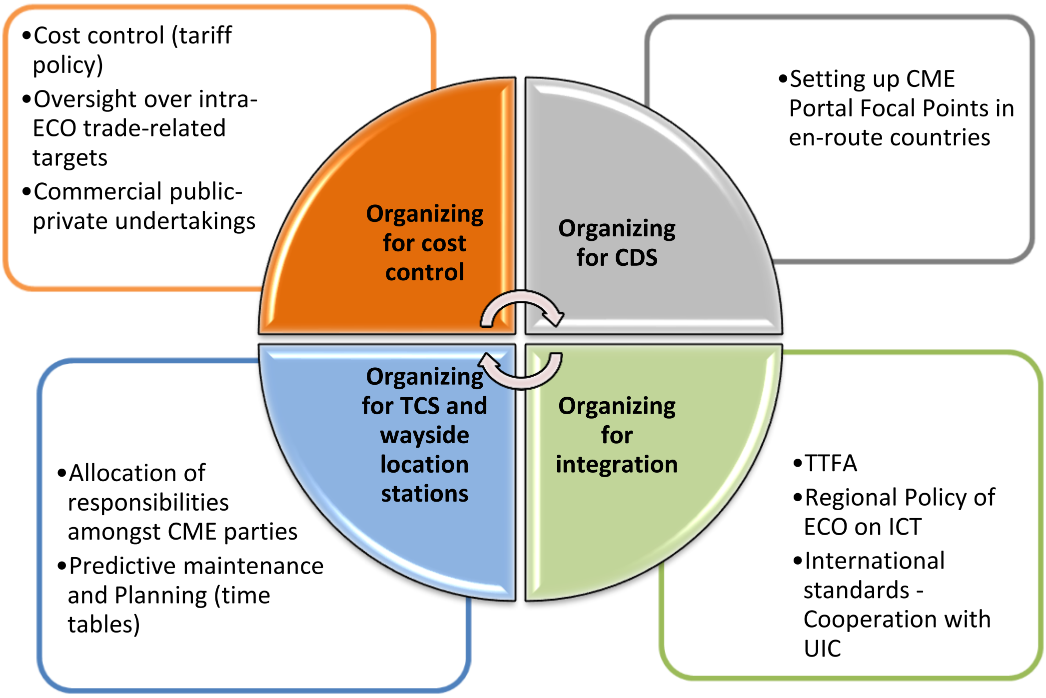


Figure 5: Capacity building targets and comprehensive short-term actions/measures to achieve interoperable sustainability

Participatory

The participatory criterion requires public-private participation in ensuring sustainable nature of the interoperability in railway operations. The existing practices in the ECO countries point that the work models of the public-private partnerships (PPP) are currently operating in Pakistan (Tillmann Sachs, 2007), p.76, Türkiye, Kazakhstan, Azerbaijan and Iran. As an example, the memorandum of understanding on the ITI railway route has been so drafted as to embed the PPPs in processes of rehabilitation and upgradation of the main railway lines; the construction on the Qazvin-Rasht-Astara railway link (Map 3: Route 3) is on the concessions basis; the operations of Nomad Express train on segments of the Istanbul-Almaty & Almaty-Bandar Abbas railway corridor (Map 2: Route 2) and on Baku-Tbilisi-Kars railway line are private. To that effect, railway operations on ECO's railway routes opt to be inclusive of PPP patterns through the CME. From the point of the

[2] Short-term period in the context of this paper spans for up to 3 years from 2018.

operational efficiency, the PPPs have been reported to entail up to 40 percent as Asian practices indicate (Guariano, 2014). In that context, the targets in achieving the sustainable nature of railway operations while, at the same time, maintaining operational interoperability amongst parties involved in ECO's railway corridors may include the following three targets: (1) involving financially sound partners to improve and upgrade ECO's railway operations; (2) ensuring operational efficiency and cost effectiveness within ERN; (3) instituting auxiliary legal modalities for enabling PPP participation in regional rail transport operations. These targets would need to be met by implementing the following four actions/measures to: (i) design and develop PPP operational patterns for ERN-specific operations; (ii) ensure facilitative legal instruments to involve PPP participation in CME's functioning; (iii) organize the regional forum for cooperation on regional infrastructure projects with participation of third parties in project co-financing; (iv) test operational patterns of PPP in practice. The PPP structures will undoubtedly add complexity in the multi-dimensional and multi-level operating structure of railway regional projects (Mazouz, 2008) but they will ensure green and brown field projects with numerous interfaces "to be managed and integrated for operational efficiency" (IRSE, 2018).

5. Discussions

In this section, with the objective of examining the technical implications of new technologies in railway and thus developing the model of interoperability, the stewardship of the five criteria has been deployed. Those criteria enabled the sourcing of the input data for the model. The quantity and designation of the input data have been aligned with their descriptions in the previous sub-sections of this paper. Accordingly, the set of 30 targets and the set of 40 required actions/measures have been identified and developed under the objective of exploring whether those will produce the sustainable level of the interoperability in railway operations in ECO. In the analysis, the methodology of linear regression analysis has been applied, as follows:

Table 8: Inputs to calculations of the least squares equation

	Targets	Actions			
	X	Y	X2	XY	Y2
Capacities	7	9	49	63	81
Systemic	9	12	81	108	144
Economic	6	8	36	48	64
Operational	5	7	25	35	49
Participatory	3	4	9	12	16
	30	40	200	266	354

Formulas (1) and (2) has been formed to calculate values of *a* and *b*:

$$\boldsymbol{b} = \frac{n(\sum XY)-(\sum X)(\sum Y)}{n(\sum X^2)-(\sum X)^2}; \quad (14)$$

$$a = \frac{\sum Y}{n} - b\frac{\sum X}{n} \; or \; \overline{Y - b\bar{X}}; \quad (15)$$

$$a = \bar{Y} - b\bar{X}; \quad (16)$$

By substituting numeric values in formula (1) we obtain the numerical value of *b* and then *a*:

$$= \frac{5(266) - (30)(40)}{5(200) - (30)^2}; \quad = \frac{40}{5} - 1.3\left(\frac{30}{5}\right); = \frac{1{,}330 - 1{,}200}{1{,}000 - 900}; \quad = 8 - 7.8; = \frac{130}{100}; = 0.2 = 1.3$$

Graphically, the computations have resulted as in Figure 6 below:

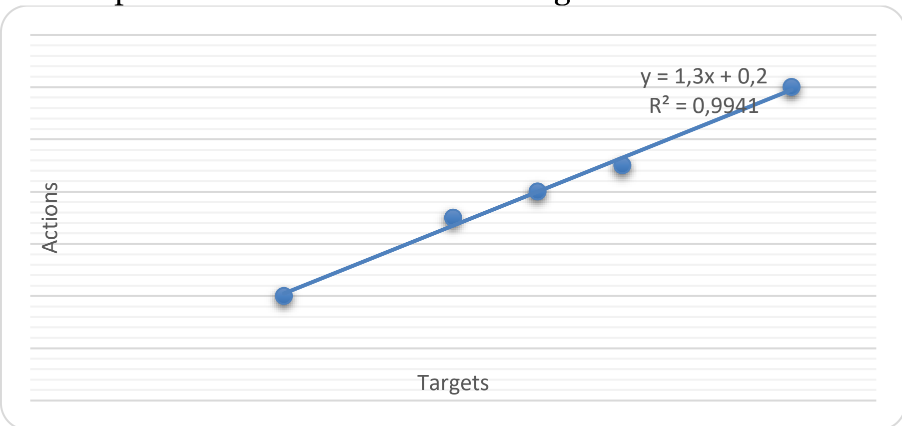


Figure 6: Targets and actions to meet the interoperability sustainability

The computations showed that the slope is positive, 1.3 indicating that the targets of the interoperability meet the adequate levels of sustainability. If the proposed model of the interoperability be maintained matching the actions/measures to be undertaken against the targets identified by the sets of the criteria chosen under each of the five dimensions, the model will ensure the sustainability levels in proportions of 1:1.3. The coefficient of determination R^2 equals 0.999 indicating that 99.9 percent of variation in the total of the forty actions/measures to be implemented by the member countries' railway networks in order to achieve sustainability of the proposed interoperability model has been explained by the five sets of the targets identified under each of the criteria specified for that purpose.

6. Results

The objective of this section of the paper was to reveal the technical implications of the new technologies in regional railway. For that, this section explored the operational interoperability on ECO's railway routes as one of the technical managerial efficiencies evolving from the advent of new technologies. Thus, the ECO region consisting of the ten member countries has been explored as the area of observation for the operational interoperability. The area has been structured into diverse dimensions in line with the key orientation and types of activities of the ECO region. For each of these dimensions, the steering criterion has been specified though analyzing the critical components within each dimension in order to identify key targets in each dimension to match those with interoperable actions/measures so that the latters be capable of ensuring sustainability through the interoperability model. The assumptions made in the investigations were such that: if the results turn out to be positive then the constructed interoperable model will ensure the desired sustainability.

Based on the outcomes of the analyses, the model has proven to ensure the required sustainable interoperability on railway corridors of the region. Specifically, the model integrated the multiple dimensions that were built on the guiding criterion in each of the five dimensions. It also presented the structured multi-dimensional railway operations that have proven interoperable and sustainable through the model, if the actions/measures envisaged in the model be implemented as designed.

In sum, the model's technical dimension proves that it enables sustainable track life by prolonged renewal cycles, therefore supporting the sustainable rail transport. The model ensures predictive maintenance as it provides key data concerning technical conditions of the train operation, including on the status of wheels, axle loads, cumulative operating load and travelling speed. All these features have been envisaged in the work plan under the technical dimension. In its cognitive dimension, the model ensures comprehensive short-term capacity building on all dimensions of the interoperability model. The detailed activities have been formulated in the work plan under the cognitive dimension. In its regulatory dimension, the model arranges for harmonizing the regulations, norms, standards in line with the guidelines of the TTFA. Cooperation within regulatory frameworks of the UIC and CAREC specializing on railway transport has been envisaged in the work plan under the cognitive dimension. In its economic dimension, the model accounts for commercialization of railway operations in the ERN. It also accounts for trade to interact with sustainable transport in the same respect as it envisages interaction with customs sub-sector and tourism sector. It advocates for establishment of measurable railway performance indicators to enable the performance-based rating of the en-route railway networks, including on railway interoperability. In its inclusive dimension, the model ensures participation-for-sustainable financing and efficiency. The inclusive nature of railway operations will be ensured at the back of the social responsibility in public-private partnership operations. The model formulated specific actions/measures to be taken in this regard. The model streamlined its content with the input data (critical components, criteria, dimensions, targets, practical actions/measures etc.) and the resulting outcome provides the following characteristics of the model:

- ✓ Single window operation;
- ✓ Simplified and common operating rule set;
- ✓ Smooth transition from one system to another;
- ✓ Common data structure;
- ✓ Monitors full range of operating conditions, infrastructure and trains;
- ✓ Provides for enforced authorities (speed along the entire corridor).

Result: Interoperability Model of Railway Corridors in the ECO region

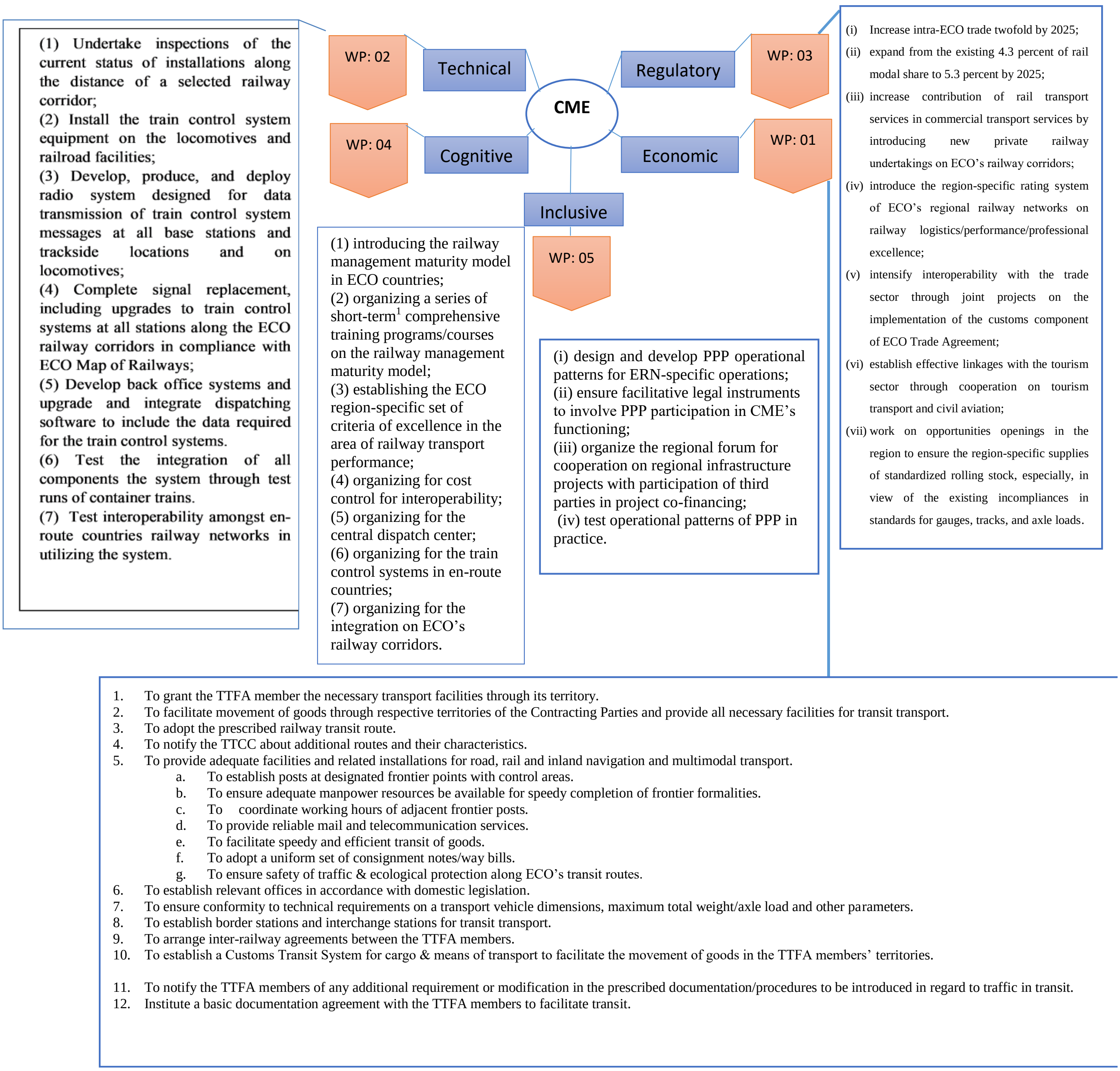


Figure 7: Interoperability model of railway routes in the ECO region

Recommendations based on the interoperability model

The recommendations entailing from the interoperability model developed under this paper include the following:

I. Set the total of 30 Targets in the five dimensions/work areas:
- (i) Capacity building: 7 targets
- (ii) Regulatory: 9 targets
- (iii) Economic: 6 targets
- (iv) Operational (railways): 5 targets
- (v) Participatory: 3 targets

II. Develop the work plan to include the total of 40 concrete practical actions/measures:
- (i) Capacity building: 9 work plan activities

(ii) Regulatory: 12 work plan activities
(iii) Economic: 8 work plan activities
(iv) Operational (railways): 7 work plan activities
(v) Participatory: 4 work plan activities

III. Set up the CME for ECO's railway corridors
IV. Organize for participation and funding, inclusive of the PPP
V. Test the interoperability model in practice

The implementation period has been identified to be from 2019 till 2025.

8. Conclusions on interoperability methods

In this section of the paper, the model of the interoperability of railway routes in the ECO region is expected to positively impact sustainability of the regional ECO Transport Network (ETN). That is being asserted on the ground of clear targets emerged, under this section of the paper, in the five instrumental dimensions of the ECO Railway Network (ERN). Deriving from the critical elements in each of the five dimensions of the ERN while, at the same time, equipped with the three core development principles, the specified 30 targets will be met by 40 concrete activities of 5 work plans under the proposed interoperability model. The latter proved to comfortably match the interoperability targets with practice-oriented actions which, through the functionalities of the interoperability model, will ensure sustainability of the ETN. The model will bring in greater efficiency owing to the involvement of new railway operator undertakings via public-private partnerships at the back of their sustainable financing of regional infrastructure projects. The technical and operational functionalities of interoperability will be handled by the CME, ECO-specific corridor management entity. Cooperation within the common regulatory space on the interoperability amongst the ECO, UIC and CAREC has been envisaged in the region's transit transport framework agreement, TTFA. The resulting model, if successful, will be replicated across the 480 million people region. The impact is expected to have spillover effects onto the inter-regional scale as the technical standards have been derived from the larger scale regional international partner organizations such as the UIC.

Reference list

Boskovic B. & M. P., 2018, *Concept of Interoperability in the Railway System of Europe*. Belgrade: University of Belgrade.

Dalmo, M., Feb 2019, Efficiency in rail transport: Evaluation of the main drivers through meta-analysis with resampling. *Transport Research Part A: Policy and Practice , 120*, 83-100.

ECO, 17-18 May 2017, 16th Meeting of the TSCC. Tbilisi.

ECO-ITU Joint Study on ICT, 2017, Tehran: http://www.eco.int/elib/85651-Joint-ECO-ITU-Study-on-ICT-needs-of-ECO-Member-States.html?t=E-Library.

Edquist, C., 2019, Towards a holistic innovation policy: Can the Swedish National Innovation Council (NIC) be a role model? *Research Policy , 48* (4), 869-879.

Ferrari, P., 2018, Some necessary conditions for the success of innovations in rail freight transport. *Transportation Research Part A: Policy and Practice , 118*, 747-758.

Guariano, M., 2014, Looking forward. *PM Network 28 (1)* , 34-44.

Hayat, S., 2017, Modeling of interface dialog between train and balise location by sginaling system ERTMS in dysfunction cases. *Procedea de Universite de Technology Belfrot-Monbeliard* , 618-627.

ICT Ministerial, 2017, December 5). *2nd Ministerial Meeting on ICT*. Retrieved from http://www.eco.int/general_content/86811-Report-of-the-2nd-Meeting-of-ECO-Ministers-of-ICT.htmlt=General-content

Jarasueniene, A., 2017, Analysis of Management Application Theories and Methods of Developing Railway Transportation. *Proceedia Engineering* , 173-184.

Jayani R.P. et al, 2018, Relationship between innovation capability, innovation type, and firm performance. *Journal of Innovation & Knowledge , 3* (1), 44-55.

Lorenzo, M. et al, 2013, An analytical approach to calculate the capacity of a railway system. *European Journal of Operational Research , 228* (1), 11-23.

Ministerial, E., 2018, *Report of the 9th Meeting of Ministers of Transport of the ECO Member States*. Ministerial, Turkmenbashi.

PMI, 2013, *Organizational Project Management Maturity Model (OPM3®) – Third Edition*.

Report of the 13th Meeting of Heads of Railway Authorities of the ECO Member States. (17-18 April, 2017)., (pp. 1-10). Baku.

RPC, 14-15 Deecember 2017, *Report of the 27th Regional Planning Council of ECO*. Islamabad.

Sarmento, J., Renneboog, L., & Verga Matos, P. (2017). Measuring efficiency by DEA approach and the Malmquist index. *EJTIR , 14* (4), 530-551.

Sergeeva, N. et al, 2018, Championing and promoting innovation in UK megaprojects. *International Journal of Project Management , 36* (8), 1068-1081.

Shaofeng, X., 2013, Transport economies of scale and firm location. *Mathematical Social Sciences , 66* (3), 337-345.

Shimoya, M., 2016, *Feasiblity Study on implementation of customs transit related provisions of ECO Transport Transit Framework Agreement*. ECO.

Shunquan, Q. &. Zongiu Gao, 2017, Developments and Prospects of Long-Span High-Speed Railway Bridge Technologies in China. *Engineering , 3* (6), 787-794.

Sohail, I., 2005, A unified strategic facility for public view. *PMI Global Congress 2005—EMEA, Edinburgh, Scotland. Newtown Square, PA: Project Management Institute.* (pp. 1-19). PMI.

ECO, 2017, The 2nd Meeting of Minister of Transport and Communications of the ECO Member States (pp. 1-10), Baku.

ECO, 12 July 2017, The 9th Meeting on ITI Container Train (pp. 1-9), Islamabad.

Tillmann Sachs, R. T., 2007, Analysis of political risks and opportunities in public private partnerships (PPP) in China and selected Asian countries: Survey results. *Chinese Management Strategies* , 123-148.

Tramboulas, D., 2012, *ECO Railway Network Development PLan*. Tehran.

World Bank, 2010, *Policy Research Working Paper No.5329*. Retrieved May 2019 2019, from WB: http://documents.worldbank.org/curated/en/249851468161954392/pdf/WPS5329.pdf

Yoan, H., 2017, Achieving Sustainability in Railway Projects: Major Stakeholder Concerns. Project Management Journal, *Project Management Journal,48(5)*, 115–132.