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International Cargo Flow under Improved Border-Crossing Services in Central Asia

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Abstract

This paper analyzes the expected impacts of improving border-crossing services on international freight transport in Central Asia (CA). It develops a freight traffic network-assignment model based on the user equilibrium principle and incorporating traffic congestion in the railway network and at national borders. The model covers the global transportation network, which has a total length of 2,909,252 km of roads and 128,729 km of railways in addition to maritime transport. Two cases are simulated by combining the developed network-assignment model with the global general equilibrium model. The baseline case is defined as when no border-crossing service improvements are made in CA and there is no change in transportation costs, and the improvement case assumes that border-crossing service improvements are made and transportation costs change. Trade volumes and costs are simulated in 2010, 2015, and 2020 through sequential computation. The results show that border-crossing service improvement decreases international transportation costs and significantly changes railway transportation pattern especially from East Asia to CA, whereas interregional road transport can be decreased in spite of the crossing border time reduction. The analysis thus suggests that further improvement of Central Asian transportation services is a prerequisite for the sustainable growth of regional trade.

Keywords: Cross-border freight traffic, traffic assignment, Central Asia

INTRODUCTION

Since the dissolution of the Soviet Union, the landlocked countries of Central Asia (CA), namely Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan, have become largely isolated from international markets. The World Bank (*1*) argues that poor infrastructure results in high transportation costs for landlocked countries, negatively affecting their trade relationships. One way to overcome these market barriers would be to develop a regional transportation network among the CA countries; although one was originally designed to support the planned Soviet economy, it has been poorly renovated and should now be transformed into a part of the global transportation network. The Central Asia Regional Economic Cooperation (CAREC) Program, led by the Asian Development Bank, has been promoting regional cooperation and development in CA since the late 20th century. From 2001 to 2013, the program invested US$22.4 billion in regional infrastructure and initiatives to promote connectivity and trade, particularly helping the landlocked countries reach the global market. From 2001 to 2013, almost US$18 billion was invested in 98 CAREC-related transportation projects along the six CAREC corridor routes (*2*).

Many studies have shown the importance of infrastructure in CA (*3-9*). However, the existing research on transportation infrastructure in CA is qualitative rather than quantitative, largely due to difficult data collection and poor data reliability. This study, however, overcomes the problem of poor data availability in CA by utilizing a new integrated dataset, which was made by the authors (*10*). This paper aims to empirically analyze the economic impact of improvements to border-crossing services in CA on freight transportation costs and international trade. This is done by following the methods of Iwata *et al.* (*11*, *12*) and Shibasaki and Watanabe (*13*).

This paper is organized as follows. The next section summarizes the infrastructure development program in CA, after which the model developed to analyze interregional traffic flows in transportation networks is presented. Then, a case analysis is presented in which the impacts of improved border-crossing services in CA on international traffic flows and costs are simulated via the developed model combined with a global general equilibrium model. Finally, the paper's results are summarized and further research issues are presented.

CAREC PROGRAM

The CAREC Program is a ten-country partnership supported by six multilateral institutional partners and aimed at working together to promote development, trade, and commerce throughout the Eurasian continent. The program is divided into four sectors: transportation, trade facilitation, energy, and trade policy. The transportation arm aims to establish competitive transportation corridors, facilitate efficient cross-border movement of people and goods, and develop safe and people-friendly transportation systems. The trade facilitation sector aims to increase international trade volumes by reducing the cost, time, and uncertainty of transporting goods across borders to consumers. Transportation and trade facilitation sectors in the CAREC projects set five key quantitative goals corresponding to expansion of road corridors, maintenance of road corridors, railway modernization, service improvement at border-crossing points (BCPs), and increase in interregional trade (*14*). The CAREC road corridors were originally planned in 2007 (*15*), but the plan was revised in 2013 (*14*).

FIGURE 1 shows six major corridors projects in CAREC program. As of September 2013, approximately 4,487 km of roads and approximately 3,190 km of railways had been completed. CAREC (*16*) shows that the average border-crossing time for trucks running from Kazakhstan to Russia has been reduced from 7.7 hours in 2011 to 2.9 hours in 2012; this time reduction increased trade flows from Kazakhstan to Russia by 66% in 2011.

DEVELOPING A MODEL FOR CARGO TRAFFIC ASSIGNMENT IN CENTRAL ASIA

Model

The impacts of border-crossing service improvement in CA on interregional traffic-flow patterns are analyzed using the Multimodal International Cargo Simulation model for Central Asia (MICS-CA model). The MICS-CA model, developed by extending and improving an existing model proposed by Shibasaki *et al.* (*17*), analyzes multi-modal international freight flows.

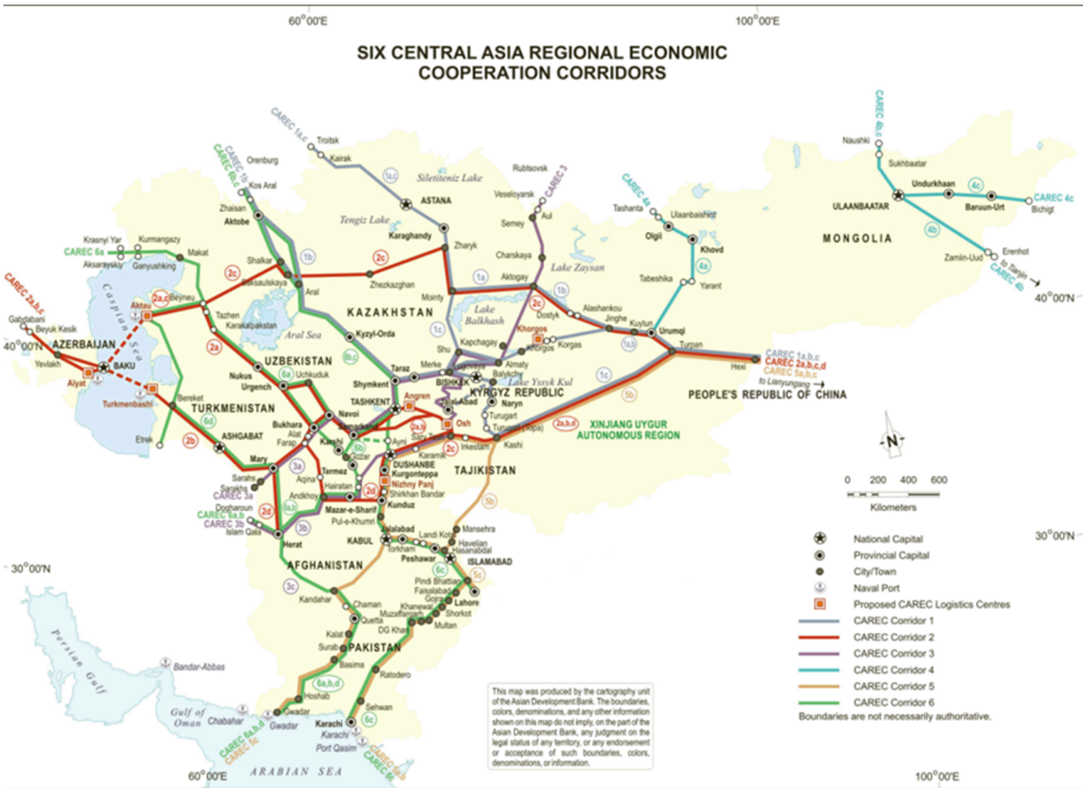

FIGURE 1 Six Central Asia Regional Economic Cooperation Corridors.

Source: ADB (*14*)

Using an inputted origin-destination (O-D) matrix of cargo flow volume, the MICS-CA model outputs traffic flows and transportation costs. The existing MICS-CA model, which mainly focuses on the maritime container shipping network, applies a simple stochastic network-assignment approach to a shipper sub-model that assigns cargoes to the intermodal transportation network, including both maritime and land shipping, without considering traffic congestion. However, the MICS-CA model developed in this paper mainly focuses on the land shipping network and hence incorporates two types of traffic congestion by using the user equilibrium assignment (UE) approach.

The UE problem is formulated as:

$$\min_{x} z(x) = \sum_{a \in A} \int_0^{x_a} G_a(x_a) dx \tag{1}$$

$$\text{subject to } x_a = \sum_{(r,s) \in O \times D} \sum_{k \in K_{rs}} \delta_{a,k}^{rs} \cdot f_k^{rs} \quad \text{for } \forall a \tag{2}$$

$$\sum_{k \in K_{rs}} f_k^{rs} - q_{rs} = 0 \quad \text{for } \forall r, s \tag{3}$$

$$f_k^{rs} \geq 0 \quad \text{for } \forall k, r, s \tag{4}$$

where $z(x)$ is an objective function, a is a link, A is a set of links, x_a is the traffic flow of the link a, $G_a(\cdot)$ is a cost function of the link a, r is an origin, s is a destination, O is a set of origins, D is a set of destinations, k is a path, K_{rs} is a set of paths for OD pair rs, $\delta_{a,k}^{rs}$ is a Kronecker delta, which is equal to 1 if link a belongs to path k for OD pair rs and 0 otherwise, f_k^{rs} is the traffic flow on path k for OD pair rs, and q_{rs} is the cargo shipping demand from r to s.

The first type of congestion incorporated into the MICS-CA model is the traffic congestion at a rail link due to the railway service capacity. There are two reasons for considering capacity constraints in the railway network but not the road network. First, according to the authors' interviews and related articles, railway capacity often influences travel time more critically than that of roads, particularly in CA and neighboring countries such as China and Russia. The second reason is that the traffic volume on many roads comes from both domestic traffic, including passenger cars and freight trucks, and international traffic, including mainly freight trucks. In most traffic statistics, there is no data recorded for the number of trucks dedicated to international transportation due to data collection difficulties. The mixed traffic makes it difficult to deduce the road capacity devoted only to international freight transportation.

The second type of congestion incorporated into the MICS-CA model is congestion at national borders. Long lines of trucks are often observed at national borders in CA; truck drivers must wait for up to a week at borders, according to the CPMM report. The process time caused by this border congestion might be a function of transit demand (traffic volume), time required for customs declarations and other procedures, and the number of booths at the border. Note that congestion at borders is not considered for railway traffic because the first type of congestion cannot be differentiated from the second type of congestion.

The congestion function for the first type of rail link congestion is estimated so that the observed shipping volume can be reproduced by the developed model; the congestion function for the second type of congestion at national borders is estimated using the observed waiting time data from 2010, as recorded by CPMM, and the observed traffic flow data at BCPs in 2010, which was collected by Tanaka *et al.* (*13*).

Model Estimation

The MICS-CA model contains unknown coefficients within the congestion functions, which are to be estimated using empirical data. An O-D traffic flow matrix, transportation network structure, and level-of-service data in the transportation network must be prepared to estimate the MICS-CA model.

Estimation of O-D Traffic Flow Matrixes

The O-D traffic flow matrix is estimated through four steps. The first is setting traffic analysis zones (TAZs). Five countries in CA (Kazakhstan, Kyrgyzstan, Turkmenistan, Tajikistan, and Uzbekistan) are divided into the administrative units in each country. This follows the zoning system developed by Shibasaki *et al.* (*17*). However, as no suitable statistical data other than Gross Regional Products (GRPs) is available that is representative for TAZs, this study estimated the TAZs-based traffic volumes assuming that the traffic volumes to and from TAZs are proportional to their GRPs. China is divided into 31 provinces following the zoning system of Shibasaki *et al.* (*17*), and Russia is divided into eight districts. Country-based TAZs are assumed for Armenia, Azerbaijan, Belarus, Georgia, India, Iran, Japan, Pakistan, Turkey, and Ukraine. Finally, the rest of world is divided into continent-sized TAZs. The boundaries of these TAZs can represent the collective transportation links feeding into CA and its neighboring regions. In sum, 104 TAZs are used in this study.

The second step is integrating the O-D matrix of cargo flows transported via land with the corresponding one for maritime shipping, both of which are obtained from the actual tonnage-based bilateral trade data by transportation mode (*18*). This study covers trade by CA countries via land and maritime transportation and trade between the Eurasian countries by land transportation to highlight the transportation in the CA. Note that the O-D matrix in the second step uses the country-zoning system.

The third step is converting the tonnage-based O-D matrix into a vehicle/container-based O-D matrix. A ton to vehicle/container ratio of 0.1 is assumed for all containers, implying that, on average, 10 tons of cargo is loaded onto a trailer or truck in CA. Although this assumption excessively simplifies the reality, poor availability of data for the number of vehicles passing through BCPs did not enable us to incorporate a variety of ratios.

The final step is estimating the 104 TAZ-based O-D traffic flow matrix using the actual country-based O-D matrixes, which are available from Global Trade Navigator (*18*). As the GRPs of provinces in Turkmenistan are unfortunately not available, the traffic volumes to and from TAZs in Turkmenistan are assumed to be proportional to their population. For a traffic flow from Country R to Country S, let the volume be represented by q_{RS}. Country R contains multiple TAZs $r(\in R)$, while Country S also contains multiple TAZs $s(\in S)$. Then the traffic volume from r to s is estimated as:

$$q_{rs} = \frac{GRP_r}{GRP_R} \cdot \frac{GRP_s}{GRP_S} \cdot q_{RS} \tag{5}$$

where GRP_R, GRP_S, GRP_r, and GRP_s represent the GRPs in countries R and S and TAZs r and s, respectively.

Establishment of Transportation Network

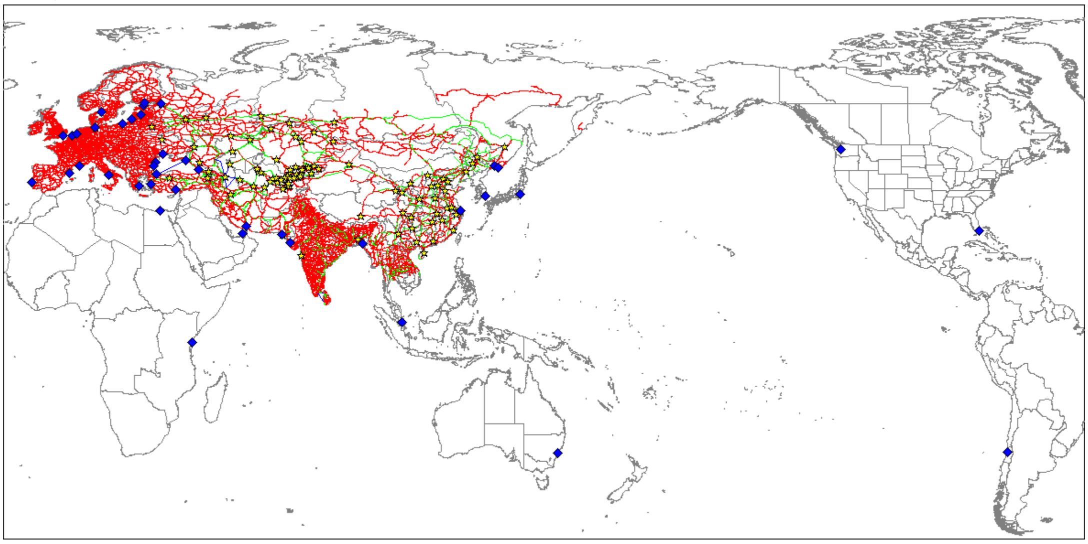

FIGURE 2 O-D Points, Ports, and Land Transportation Network in MICS-CA.

FIGURE 2 illustrates the worldwide network used in the MICS-CA model. The land shipping network for CA network, including road and rail networks, is based on the network map of the Asian Development Bank (ADB) (*15*) and the worldwide GIS-based information provided by American Digital Cartography Inc.. The existing land shipping networks for East and Southeast Asia, created by Asia-Pacific Economic Cooperation (*19*), are also utilized. Additionally the ADC WorldMap^{TM} is the information source for the networks on the rest of the Eurasian continent. The resulting land shipping network for the entire Eurasian continent coves 69,300 road links and 4,033 railway links with total lengths of 2,909,252 km of road and 128,729 km of railway. The network also includes ferry links on the Caspian Sea.

Next, the maritime network is prepared covering the seaports used mainly for international trade to and from CA in addition to the ports (one per TAZ). For analytical simplicity, a single port is assumed in China and four ports are assumed in Russia. Finally, O-D points are selected from the network nodes. Within Eurasia, O-D points are assumed to be capital and provincial capital cities in the country-based and province-based zones, respectively. Outside of the Eurasian continent, a unique O-D point is set in any continent or region that is directly connected to the ports in the corresponding continent or region using hypothetical access links.

Estimation of Link Cost Functions by Link Type

The generalized link cost for each link is generally estimated as the sum of the freight charge and the time cost, which is computed by multiplying the link travel time by the average value of time for the cargo owner. They are defined according to the type of link: road, ferry, rail, BCP, or transshipment. The rail and BCP links include link performance functions to reflect that traffic flows are interrupted by the limited capacities of rail facilities and cross-border roads.

First, the generalized cost of a road link is assumed to be:

$$G_{L,road} = C_{LF,road} + \omega \cdot T_{L,road} \tag{7}$$

$$C_{LF,road} = 2lk_{road} \tag{8}$$

$$T_{L,road} = l/v_{road} \tag{9}$$

where $G_{L,road}$ is the generalized unit cost of the road link (US$/Twenty-foot equivalent unit (TEU)), $C_{LF,road}$ is the unit freight of the road link (US$/TEU), $T_{L,road}$ is the travel time of the road link (hours), ω is the value of time (US$/TEU/hour), k_{road} is the unit variable cost per kilometer of the road link (US$/TEU/km), l is the length of the link (km), and v_{road} is the average travel speed of the road link (km/hour). The variable cost is doubled because most vehicles carry their goods only one way, transporting nothing on return trips.

Second, the generalized cost of a ferry link is assumed to be:

$$G_{L,ferry} = C_{LF,ferry} + \omega \cdot T_{L,ferry} \tag{10}$$

$$C_{LF,ferry} = C_{ferry} + 2lk_{ferry} \tag{11}$$

$$T_{L,ferry} = l/v_{ferry} \tag{12}$$

where $G_{L,ferry}$ is the generalized unit cost (US\$/TEU), $C_{LF,ferry}$ is the unit freight (US\$/TEU), C_{ferry} is the unit cost (US\$/TEU), $T_{L,ferry}$ is the travel time (hours), k_{ferry} is the unit variable cost per kilometer (US\$/TEU/km), and v_{ferry} is the average travel speed (km/hour).

Third, the generalized cost of a rail link is assumed to be:

$$G_{L,rail} = C_{LF,rail} + \omega \cdot T_{L,rail} \tag{13}$$

$$C_{LF,rail} = 2lk_{rail} \tag{14}$$

$$T_{L,rail} = l/v_{rail} \tag{15}$$

where $G_{L,rail}$ is the generalized unit cost (US\$/TEU), $C_{LF,rail}$ is the unit freight (US\$/TEU), $T_{L,rail}$ is the travel time (hours), k_{rail} is the unit variable cost per kilometer (US\$/TEU/km), v_{rail} is the average travel speed (km/hour).

Fourth, the generalized costs of BCP links (road and rail) are assumed to be:

$$G_{B,road} = C_{B,RS} + \omega \cdot T_{B,RS,road} \tag{16}$$

$$T_{B,RS,road} = T_{DX,R} + T_{DM,S} + T_{CX,R} + T_{CM,S} \tag{17}$$

$$G_{B,rail} = \omega \cdot T_{B,RS,rail} + G_{Rail,RFSU} \cdot \delta_{RFSU} \tag{18}$$

$$T_{B,RS,rail} = \left(T_{CX,R} + T_{CM,S}\right)\left\{1 + \alpha_1\left(\frac{x}{Cap_{rail}}\right)^{\alpha_2}\right\} \tag{19}$$

where $G_{B,road}$ is the generalized unit cost of the road BCP link (US\$/TEU); $C_{B,RS}$ is the unit cost of crossing the BCP from Country R to Country S (US\$/TEU), including the cost of document preparation and customs clearance in both exporting and importing countries; $T_{B,RS,road}$ is the time required to cross the road BCP from Country R to Country S (hours) including the waiting time at the borders and the time of document preparation and customs clearance in both exporting and importing countries, $T_{DX,R}$ is the document preparation time required for exporting goods from Country R (hours); $T_{DM,S}$ is the document preparation time required for importing goods into Country S (hours); $T_{CX,R}$ is the time required for customs clearance and technical control when exporting goods from Country R (hours); $T_{CM,S}$ is the time required for customs clearance and technical control when importing goods into Country S (hours); x_{contra} is the contraflow of the link (TEU/hour); $G_{B,rail}$ is the generalized unit cost of a rail BCP link (US\$/TEU), $T_{B,RS,rail}$ is the time required to cross the rail BCP from Country R to Country S (hours), $G_{Rail,RFSU}$ is the generalized cost of railway transshipment link from one gauge to another gauge (US\$/TEU), δ_{RFSU} is equal to 1 if the railway BCP locates between Former Soviet Union countries and other countries, and 0 otherwise; x is the traffic volume (TEU/year); Cap_{rail} is the flow capacity; and α_1 and α_2 are parameters. The above link functions assume that the waiting time for customs clearance and technical control at railway borders depends on only the traffic volume. Although other factors related to BCP capacity, such as the number of windows, the efficiency of the process, the commodity transported, and the customs system may also influence the border wait time, they are not included because of data unavailability.

Finally, the generalized cost of a transshipment link for transportation mode m is assumed to be:

$$G_{T,m,Load} = \omega \cdot \left(T_T + 0.5I_m + T_{DX,R} + T_{CX,R}\right) + C_{Ex,R} \tag{20}$$

$$G_{T,m,Unload} = \omega \cdot \left(T_T + 0.5I_m + T_{DM,S} + T_{CM,S}\right) + C_{\mathrm{Im},S} \tag{21}$$

where $G_{T,m,Load}$ is the generalized unit cost of the loading transshipment link for transportation mode m (US$/TEU), including expected waiting time and the document preparation, customs clearance and technical control time required for exporting goods from Country R; T_T is the time required to complete the transshipment (hours); I_m is the service interval of transportation mode m (hours); $G_{T,m,Unload}$ is the generalized unit cost of the unloading transshipment link from transportation mode m (US$/TEU), including expected waiting time and the document preparation, customs clearance and technical control time required for importing goods to Country S. This assumes that the average expected waiting time is equal to the half of the railway/ferry service headway and that cargos are not required to wait for transshipment from rail/ferry to roadway.

Estimation of Parameters in Link Cost Functions

TABLE 1 summarizes the parameters used in the model. The value of time is estimated using the monthly average salary of Kazakhstan. The average speed and unit variable cost for ferry links follow the data given by Shibasaki and Watanabe (*12*). The unit variable cost per kilometer for roads and railways are estimated using the data from Corridor Performance Measurement and Monitoring (CPMM) annual reports (*20*). The time and cost for crossing BCPs are collected from the Doing Business Report (*21*). The three parameters in the Bureau of Public Roads (BPR) function for the rail link in equation (15) are calibrated in terms of traffic assignment using the UE principle so that the observed traffic volumes at the seven BCPs (*17*) are approximately equal to the estimated traffic volumes at the BCPs because the data on the volume of rail transport is not available. The rail link flow capacity is assumed to be less than 10,000 TEU per weekday. The calibration results yield $Cap_{rail} = 26{,}00{,}000$ TEU/Year, $\alpha_1 = 1.100$, and $\alpha_2 = 1.002$. The average duration and cost to pass the railway BCP between China and Kazakhstan, which is called Dostyk – Ala Shankou, are 57.3 hours and 692 US dollars in 2011.(20)

TABLE 1 Parameters Used in Simulation Analysis

		Road	Railway	Ferry
Value of time	US$/TEU/hour	3.39	3.39	3.39
Average speed	km/hour	39.4	30.0	20.0
Service interval	Hour		24.0	168.0
Unit variable cost	US$/TEU/km	1.068	0.638	0.075
Transshipment time	Hour		24.0	4.0

Result of Traffic Assignment

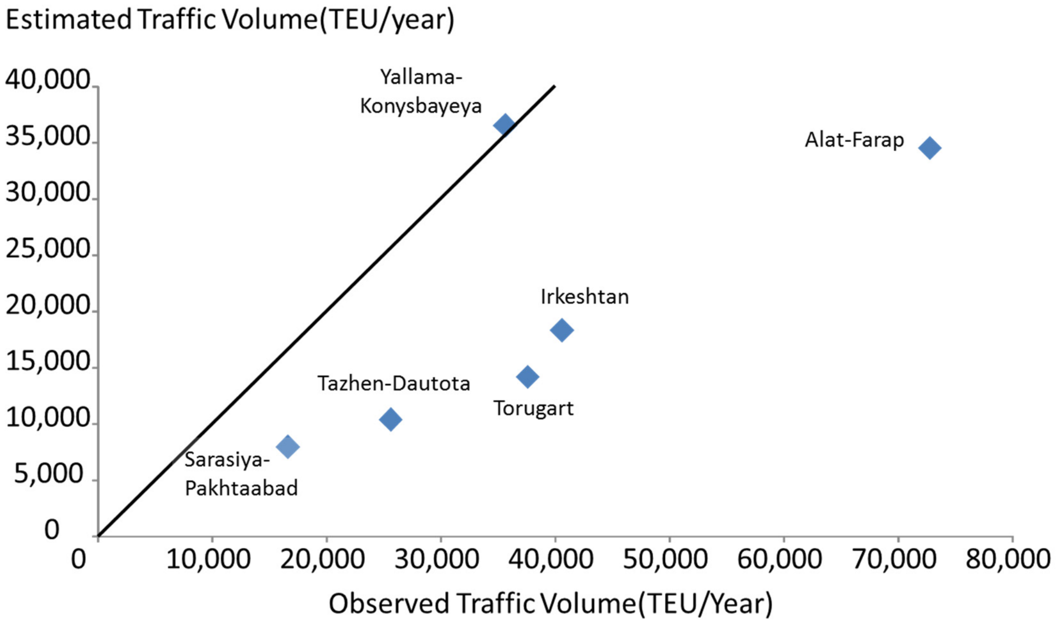

FIGURE 3 Observed Traffic Volume versus Traffic Volume Estimated with MICS-CA.

Current O-D cargo volumes are assigned to the transportation network using the above parameters to check the model's reproduction. The convergence criteria for UE assignment is $\sqrt{\sum_a \left(x_a^t - x_a^{t-1}\right)^2} \Big/ \sum_a x_a^t < 1\times10^{-7}$ where x_a^t is the link flow of link a in the t-th iteration. FIGURE 3 shows the traffic volume estimated via the MICS-CA model versus the observed traffic volume at the sic BCPs. It shows that the estimated model reproduces well the observed traffic volumes at Yallama. However, it underestimates the traffic volume at other BCPs.

CASE ANALYSIS

Approach

Potential impacts of a hypothetical case that assumes improvements in border-crossing services in CA on the regional economy and traffic flow patterns are analyzed using the Global Trade Analysis Project (GTAP) model (*22*) and the MICS-CA model developed by the authors. The analysis considers two cases: a baseline of no border-crossing service improvement and no change in transportation costs, and an improvement case in which border-crossing services are improved and transportation costs change. The improvement case assumes that the border-crossing time in CA is 35% lower in 2020 than in 2010. This aligns to the target milestone set by CAREC, which stipulates that average border-crossing time along the CAREC corridors will be reduced to 5.7 hours (*20*). The establishment of a customs union and the modernization of customs clearance procedures are also assumed to reduce the waiting time at BCPs, which is expected to contribute to achieving this target milestone. The equilibrium trade volumes and costs are estimated through iterative computation of GTAP and MICS-CA models.

The GTAP model is a spatial computable general equilibrium model, which covers multiple sectors in multiple regions assuming perfect competition and constant returns to scale (*22*). First, the monetary-based O-D flow matrixes in 2010, 2015, and 2020 are estimated via the GTAP model. This is the baseline case. For the estimation, changes in the following factors within each region are forecast: population; skilled labor; unskilled labor; capital; natural resources; total factor productivity; and the customs union between Belarus, Russia, and Kazakhstan (*23*). Then, the status of the international economy in 2010, 2015, and 2020 is estimated via three sequential simulations. The first simulation estimates changes from 2007 to 2010 by inputting changes in the above factors into the GTAP model, along with 2007 data. The second simulation estimates changes from 2010 to 2015 by inputting changes in the above factors into the GTAP model along with the 2010 data estimated in the first simulation. The third simulation estimates changes from 2015 to 2020 by inputting changes in the above factors into the GTAP model, along with the 2015 data estimated via the second simulation. The detailed data inputted into the GTAP model in the case analysis is shown in Tanabe *et al.* (*24*).

Next, the monetary-based O-D flow matrixes in 2015 and 2020 are estimated through iterative computation using the GTAP and MICS-CA models assuming that the border-crossing time in CA is reduced. This represents the improvement case. Theoretically the iterative process should continue until both the trade volumes in 2020 output from the GTAP and the traffic flows and the transportation costs in 2020 output from MICS-CA reach the convergences. However, the iterative computation was implemented only once due to the time constraint in our study.

Results

FIGURE 4 shows the change in simulated international traffic flows in 2020 by 35% crossing border time reduction. Red lines show the links where the traffic flows are increased while blue lines show the links where the traffic flows are decreased. First, the railway connecting China with Kazakhstan becomes more economically competitive than the railway in Russia is. The traffic volumes at railway border between China and Kazakhstan, where is called Dostyk- Ala Shankou, is increased by more than 200%. The decreased traffic volume of Russian railway is almost same as the increased traffic volume of Chinese railway.

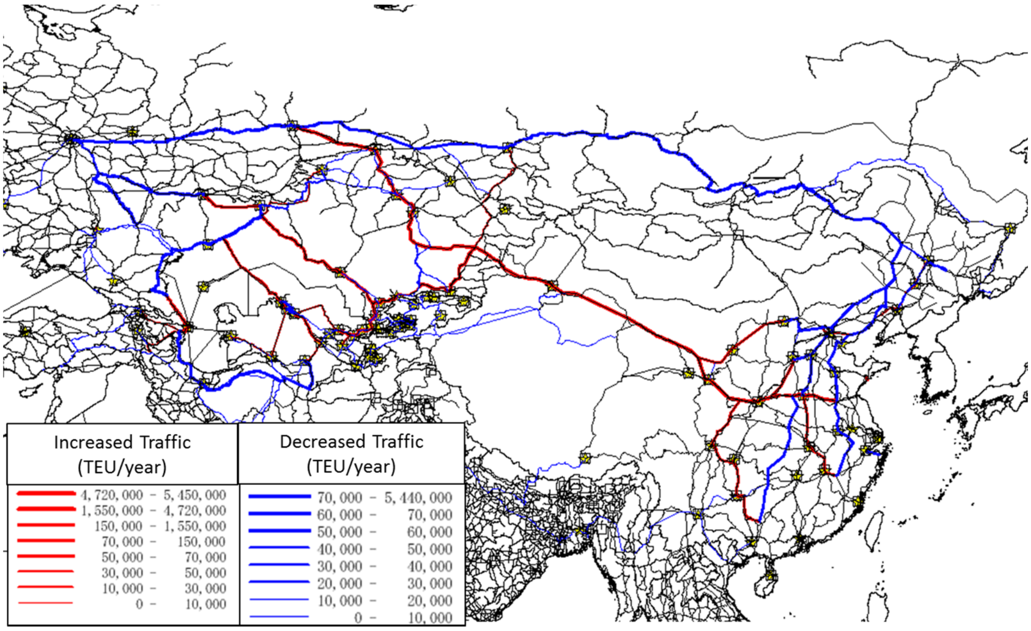

FIGURE 4 Simulation Results of Change in International Cargo Flow by Crossing Border Time Reduction

Next, the road international trade in Tajikistan and Kyrgyzstan are decreased by the crossing border time reduction. For example, traffic flows of Irkesthan and Torugart, where are the roads crossing border between Kyrgyz and China, are decreased by 52% and 71% respectively even though the crossing time of Irkesthan and Torugart are reduced.

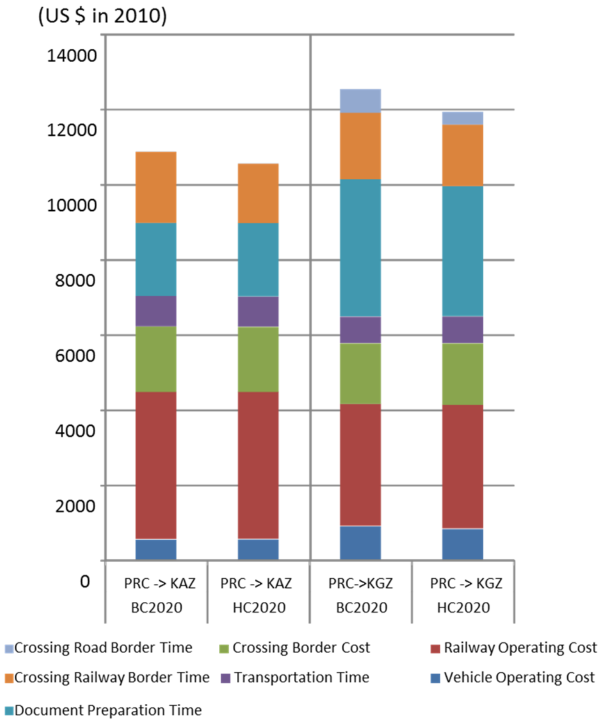

FIGURE 5 Simulation Results of breakdown of the average trade cost from China to Kazakhstan and Kyrgyzstan.

FIGURE 5 Simulation Results of breakdown of the trade cost between China and Kazakhstan and China and Kyrgyzstan.. FIGURE 5 helps us to understand the changes in traffic flow shown in FIGURE 4. Though the both export cost from China to Kazakhstan and Kyrgyz are decreased by around 3 %, the export cost from China to Kazakhstan is decreased by the crossing railway border time reduction while the export cost from China to Kazakhstan is decreased by the crossing road border time reduction. The largest constrain of the Chinese trade with CA is the Dostyk – Ala Shankou railway border, which is 25% of total trade cost between Kazakhstan and China. The huge crossing time reduction at Dostyk – Ala Shankou BCP boosts the Chinese trade by railway, and reduces the crossing road border trade with Kyrgyzstan.

CONCLUSIONS

This paper developed a computable model to estimate the impacts of border-crossing service improvement on traffic flow patterns in Central Asia. Using this model and the GTAP model, two cases were then simulated. The results showed that border-crossing service improvement decreases international transportation costs and significantly change the trade pattern by railway especially from East Asia to CA, whereas interregional road transport can be decreased in spite of the crossing border time reduction.

There are numerous issues that should be addressed through further research. First, the cost functions used in this study did not fully address all transportation issues in CA. For instance, the model assumed that traffic congestion in rail links is formulated as the BPR functions at railway BCP, but in reality, railway traffic congestion would not influence the link crossing border time but would influence waiting times for transshipment. Differences in capacities and services at logistics hubs would affect the transshipment time at intermodal points but were not explicitly considered in our model. Although our approach was able to approximate such traffic congestion in transshipments, more detailed formulation would improve the reliability of the MICS-CA model. Second, the model assumed that the average border-crossing time is dependent only on the traffic flows, whereas it is also influenced by other factors. For example, CAREC (*17*) reports that the newly introduced customs union makes the customs clearance process complex and causes delays in border processes. These factors should be examined to enable better estimation of process times at the borders in the case of congestion. Third, the analysis used the data agglomerated by Tanaka *et al.* (*13*) in order to overcome poor data availability. The data was collected from the customs, but the reliability of customs data is also argued by some experts. Roman *(3)* used the unit cost value (US$/kg) to check the reliability and concludes the Chinese data on exports to CA could be used safely to estimate traffic flows. More international cargo flow data for CA would help further validate the model.

Additionally, a stochastic approach such as the Stochastic User Equilibrium could be applied to route choice or modal choice in the MICS-CA model if more data on international cargo flows were available. Fourth, the vehicles/containers-based O-D matrix for land transportation was estimated on the assumption that an average of 10 tons of cargo is loaded on a trailer or truck in CA. Additional statistical data or further interviews with local stakeholders regarding the number of border-crossing vehicles could improve the accuracy of this estimated ratio. Finally, the paper applied the developed model to a limited number of cases, but other cases could be investigated to reflect the CAREC-related policies.

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