The Western Balkans

Corridor Performance Measurement and Monitoring (CPMM) System

www.cpmms.net

Developing a Digital Platform for Pilot Corridor Vc in Bosnia and Herzegovina and a Roadmap for Regional Scale-Up

December 21, 2018
### Acronyms and Abbreviations

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
<th>Country / Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>AADT</td>
<td>Annual average daily traffic</td>
<td>Macedonia</td>
</tr>
<tr>
<td>ALB</td>
<td>Albania</td>
<td></td>
</tr>
<tr>
<td>AVG</td>
<td>Average</td>
<td>Montenegro</td>
</tr>
<tr>
<td>AWS</td>
<td>Amazon Web Services</td>
<td>North border</td>
</tr>
<tr>
<td>CDN</td>
<td>Contents Delivery Network</td>
<td>November</td>
</tr>
<tr>
<td>CO</td>
<td>Carbon monoxide</td>
<td>Nitrogen oxides</td>
</tr>
<tr>
<td>CPMM</td>
<td>Corridor Performance Measurement and Monitoring</td>
<td>Open Street Map</td>
</tr>
<tr>
<td>CRO</td>
<td>Croatia</td>
<td>Soot particles</td>
</tr>
<tr>
<td>DB</td>
<td>Database</td>
<td>Post meridiem</td>
</tr>
<tr>
<td>DD</td>
<td>Day</td>
<td>Planning time index</td>
</tr>
<tr>
<td>EEA</td>
<td>European Environment Agency</td>
<td>Relational Database Service</td>
</tr>
<tr>
<td>EMEP</td>
<td>Evaluation Program</td>
<td>Reduce factor</td>
</tr>
<tr>
<td>EP</td>
<td>Emission factors</td>
<td>Republika Srpska</td>
</tr>
<tr>
<td>ETL</td>
<td>Extract, transform, and load</td>
<td>South border</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
<td>South East Europe Transport Observatory</td>
</tr>
<tr>
<td>EUR</td>
<td>EURO</td>
<td>Serbia</td>
</tr>
<tr>
<td>FREQ</td>
<td>Frequency</td>
<td>Secure Shell</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
<td>Transport Data Management System</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information System</td>
<td>Trans-European Transport Network</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
<td>Time</td>
</tr>
<tr>
<td>HH</td>
<td>Hour</td>
<td>Travel time index</td>
</tr>
<tr>
<td>Hr</td>
<td>Hour</td>
<td>User interface</td>
</tr>
<tr>
<td>IAM</td>
<td>Identity and Access Management</td>
<td></td>
</tr>
<tr>
<td>ID</td>
<td>Identity Document</td>
<td>Uniform Resource Locator</td>
</tr>
<tr>
<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
<td>United States Dollar</td>
</tr>
<tr>
<td>mm</td>
<td>Kilometer</td>
<td>Web Application Server</td>
</tr>
<tr>
<td>KOS</td>
<td>Kosovo</td>
<td>World Bank</td>
</tr>
<tr>
<td>KOTI</td>
<td>The Korea Transport Institute</td>
<td></td>
</tr>
<tr>
<td>LOS</td>
<td>The level of service</td>
<td>Year</td>
</tr>
<tr>
<td>MKD</td>
<td>Macedonia</td>
<td></td>
</tr>
<tr>
<td>MM</td>
<td>Month</td>
<td></td>
</tr>
<tr>
<td>MNE</td>
<td>Montenegro</td>
<td></td>
</tr>
<tr>
<td>NOV</td>
<td>November</td>
<td></td>
</tr>
<tr>
<td>OSM</td>
<td>Open Street Map</td>
<td></td>
</tr>
<tr>
<td>PM</td>
<td>Post meridiem</td>
<td></td>
</tr>
<tr>
<td>PTI</td>
<td>Planning time index</td>
<td></td>
</tr>
<tr>
<td>RDS</td>
<td>Relational Database Service</td>
<td></td>
</tr>
<tr>
<td>RF</td>
<td>Reduce factor</td>
<td></td>
</tr>
<tr>
<td>RS</td>
<td>Republika Srpska</td>
<td></td>
</tr>
<tr>
<td>SB</td>
<td>South border</td>
<td></td>
</tr>
<tr>
<td>SEETO</td>
<td>South East Europe Transport Observatory</td>
<td></td>
</tr>
<tr>
<td>TDMS</td>
<td>Trans-European Transport Data Management System</td>
<td></td>
</tr>
<tr>
<td>TEN-T</td>
<td>Trans-European Transport Network</td>
<td></td>
</tr>
<tr>
<td>TT</td>
<td>Time</td>
<td></td>
</tr>
<tr>
<td>TTI</td>
<td>Travel time index</td>
<td></td>
</tr>
<tr>
<td>UI</td>
<td>User interface</td>
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<tr>
<td>UPC</td>
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<tr>
<td>URL</td>
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<tr>
<td>US</td>
<td></td>
<td></td>
</tr>
<tr>
<td>USD</td>
<td>United States Dollar</td>
<td></td>
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<tr>
<td>WAS</td>
<td>Web Application Server</td>
<td></td>
</tr>
<tr>
<td>WB</td>
<td>World Bank</td>
<td></td>
</tr>
<tr>
<td>YY</td>
<td>Year</td>
<td></td>
</tr>
</tbody>
</table>
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Executive Summary

Trade and transport bottlenecks were identified as key impediments contributing to high transport costs and poor reliability of supply chains, thereby raising the cost of doing business and ultimately diverting potential investments and jobs from the Western Balkans (WB). Addressing these impediments which include physical bottlenecks as well as non-physical barriers is critical to regional integration and necessitates the implementation of significant improvements on transport corridors. Estimated roughly at about €8,140 million, which is about 5 percent of the total regional GDP for the period 2014-2020, these investment needs constitute a large financial burden on the budget of the governments in the Western Balkan region and therefore require careful planning and prioritization of projects aligned with available financing from national, European Union (EU) and private resources.

The countries of the Western Balkans, however, lack adequate monitoring systems needed to assess the performance of the key corridors/routes of the regional transport network, therefore limiting the ability to identify priority projects to upgrade and improve connectivity within the region and to the broader EU area.

In order to address this gap and to improve the performance of trade and transport corridors in the Western Balkans, the World Bank initiated a pilot project (phase 1) in 2015 to measure and monitor corridor performance in the region with a focus on automated transport data collection and data integration, and to develop a conceptual design for an ICT-based pilot system. Corridor Vc, which runs north-south through Bosnia and Herzegovina, linking the northern border to the Port of Ploče in Croatia, was selected as the pilot corridor for measuring and monitoring performance.

This report deals with phase 2 of the project to build on phase 1 by developing relevant performance metrics, expand system capabilities to develop the prototype for a Corridor Performance Measurement and Monitoring (CPMM) System for Corridor Vc, and to propose a detailed roadmap for rolling out the system to corridors and routes in the rest of the Western Balkans.

The report serves as a guidance tool for the CPMM System prototype and delves into details regarding data sources and collection, methodologies employed in developing the indicators and the prototype and describes the processes in terms of their requirements, development and implementation. The main deliverable of phase 2 of the Project is the prototype of the digital platform itself – the CPMM System that is expected to be housed in and maintained by SEETO (and later its successor, the Transport Community Treaty). The system can be accessed at the following link: www.cpmms.net
In terms of data collection and methodology, a summary of the requested data and their availability for phases 1 and 2 and the explanation of the methods developed and applied for the Project, such as map matching and geo-fence method are presented in Sections 2 and 3. The development and application of the performance indicators - nine indicators in four categories - defined and presented for measuring performance along pilot Corridor Vc, including the following:

<table>
<thead>
<tr>
<th>Category</th>
<th>Indicators</th>
</tr>
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<tbody>
<tr>
<td>I. Time and reliability</td>
<td>- Travel time and speed by roadways and railways</td>
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<tr>
<td></td>
<td>- Travel Time Index and Planning Time Index</td>
</tr>
<tr>
<td></td>
<td>- Border Clearance time</td>
</tr>
<tr>
<td>II. Cost</td>
<td>- Delay and delay cost</td>
</tr>
<tr>
<td>III. Emission</td>
<td>- Emission</td>
</tr>
<tr>
<td>IV. Reliability</td>
<td>- Reliability</td>
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</tbody>
</table>

The CPMM System prototype system is developed using the Amazon Web Cloud System, which demonstrates numerous benefits of system development on the web such as easy system configuration and expansion, handy development environment, and convenient maintenance.

Section 4 presents a detailed roadmap for a strategic regional plan for scaling-up implementation of the system throughout the Western Balkans. It provides the vision for the introduction of the CPMM system and its rolling out for different corridors and routes on the regional network; and a time-bound action plan for Corridor Vc that includes detailed schedules regarding the design and construction of the required database and systems, system installation, data collection, analysis and dissemination, capacity-building and outreach. It also includes institutional, legal and financial elements needed for implementation and recommendations for the use and institutionalization of the Transport Data Management System (TDMS) in transport polices.

Phase 2 of this activity, with the development of the CPMM System prototype, demonstrates how traditional transportation data management systems can be successfully implemented using new trends such big data analysis in transportation and a web-based internet cloud system. Based on the prototype developed during this phase and feedback received from stakeholders, it is recommended that during the third and final phase of this activity the CPMM system for the entire Western Balkan be developed and expanded. More specific recommendations are included in the report.
1. **Introduction**

1.1. **Project Background**

Connectivity and regional integration are important goals for the Governments of the Western Balkans. These goals are supported by the EU, international financial institutions and other development partners. The Bank has been supporting the connectivity agenda in the Western Balkans through lending projects for roads, railways, and ports that form part of Corridor X in Serbia and Corridor VIII in fYR Macedonia, for ports in Croatia (Rijeka and Ploče), and through policy advice for enhancing railway efficiency in Bosnia and Herzegovina, Croatia and Serbia.

In addition, the Bank recently approved a regional lending project to boost regional integration and facilitate trade in the Western Balkans starting with three countries – Serbia, Albania, and fYR Macedonia. This Project aims to support Western Balkan governments’ economic integration by (1) facilitating cross-border movement of goods, (2) enhancing transport efficiency and predictability, and (3) enhancing market access for trade in services and investments. The Corridor Performance Measuring and Monitoring tool is expected to provide a practical and systematic way for monitoring the implementation of the desired improvements for this regional lending project.

The Regional Balkans Infrastructure Study (REBIS) update carried out by the Bank, in close collaboration with SEETO, in 2015 helped identify transport bottlenecks and priority projects for South East Europe and provided a Priority Action Plan for enhancing the efficiency of the SEETO Comprehensive Network.¹ This study demonstrated that the region lacked monitoring systems needed to assess the performance of the key corridors/routes of the SEETO Network, therefore limiting the ability to identify impediments and assess progress in relieving them. This related to travel times and speeds along transport routes, as well as time spent waiting, and carrying out the necessary formalities, at border crossings. In the absence of a baseline measuring corridor performance, identifying the bottlenecks and regularly monitoring improvements, it becomes extremely difficult to assess progress in addressing the constraints and the impact they may have on overall corridor performance.

Addressing this problem requires developing a reliable and sustainable transport data management system (TDMS) for identifying bottlenecks and monitoring improvements in the Western Balkans. The development of the system has been executed in in two phases thus far:

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¹ The Comprehensive Network is defined as a multimodal regional transport network defined under the Memorandum of Understanding (MoU) signed by the Governments of Albania, Bosnia and Herzegovina, Croatia, the former Yugoslav Republic of Macedonia, Montenegro and Serbia and the United Nations Mission in Kosovo and the European Commission. It is a commonly agreed main and ancillary transport infrastructure in the South East Europe (SEE) which is the base for the implementation of the transport investment programs.
Phase 1, which was completed in 2017, includes the design of the methodology for performance monitoring evaluation taking into account data availability and sustainability considerations. The design has been tested on Corridor Vc in BiH, by piloting data collection (including from Global Positioning System (GPS) tracking) and data integration mechanisms to define cargo/truck travel times along road sections and analyze the nature and causes of the corridor’s impediments. Corridor Vc which runs primarily through BiH with two sections in Croatia was selected as a pilot, despite low traffic volumes, because both countries recognize its importance and are therefore committed to its choice as a demonstration corridor. In addition to Corridor Vc being BiH’s most important transport route, the Bank’s engagement in the transport sector in both countries further enhances the probability of project success. The Bank is currently engaged in rail and road activities in BiH; and in ports and rail in Croatia with a recently closed Project in the Port of Ploče which serves Corridor Vc.

Phase 2, which is the focus of this report, builds on Phase 1 to expand system capabilities to include a set of key performance parameters for monitoring, testing various technological solutions for cost efficient system management and maintenance, exploring win-win arrangements for data collection and data sharing among data providers for system sustainability; and preparing for a full scale system deployment on Corridor Vc and presenting a master plan and roadmap for its expansion to other corridors in the Western Balkans. This activity has been funded by a grant from the Korea World Bank Group Partnership Facility (KWPF).

Both phases of this activity have received the support of the DG NEAR and the DG MOVE, and SEETO, the latter of which represents the Governments of the WB6. Implementation is being closely coordinated with these bodies particularly SEETO where the system is expected to be housed and managed. The recent signing of the Transport Community Treaty for the Western Balkans, to succeed SEETO as the regional transport body, will further bolster the prospects for the sustainability of the system. The Transport Treaty provides a strong legal basis for collaboration (relative to SEETO), and a higher and more assured level of financing.

1.2. Phase 2 objectives and scope of work
The ultimate objective of phase 2 was to develop a TDMS prototype – the CPMM System - to support monitoring of the movement of trucks and trains between the Port of Ploče and Slavonski Brod (CRO) and Brod (BiH) border crossings along Corridor Vc as well as along the routes (corridor network) within the zone of immediate impact of the Corridor. Phase 2 of the activity was developed to meet the following objectives:

i. To develop a methodology and key set of indicators for measuring Corridor Vc performance

This component includes developing methodologies for assessing:

• Travel speed
• Traffic volumes and freight volumes
• Average travel time, average speed, frequency of low speed and speed predictability by direction on corridor
• Delay time and delay cost on specific road segments of the corridor
• Travel reliability by direction
• Time spent at areas of interest, such as border crossings, customs offices, customs terminals and the port\(^2\), including idling and stoppage;
• GHG emissions associated with truck travel along the corridor including idling time.

The corridor network for railway transport is predefined and consists of Corridor Vc route (Port of Ploče-Croatian border-Capljina-Mostar-Konjic-Sarajevo-Kakanj-Ženica-Doboj-Bosanski Šamac-Croatian border) and SEETO Route 9a (Croatian border-Dobrljin-Banja Luka-Doboj-Tuzla-Zvornik-Serbian border).

**Figure 1: Corridor Vc by mode of transport**

\(<\text{Corridor Vc Road}^3>\) \hspace{1cm} <\text{Corridor Vc Rail}>\n
**ii. To develop a TDMS prototype of Corridor Vc – the CPMM System**

The second component of this phase of the activity is to develop the TDMS prototype – a digital tool to measure and monitor performance along Corridor Vc. The prototype – the CPMM System - analyzes and reports on the performance indicators mentioned above. The visualization of the performance parameters include interactive graphs, reports and GIS based presentation by time period, location and transport mode. The prototype was developed in the cloud-based environment as a short-term solution to demonstrate benefits of the CPMM System to its users in the region without installing hardware and software required for the complete version of the system.

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\(^2\) Port of Ploče is currently upgrading their IT System implementing PCS (Port Computer System). As a result, Port procedures data exchange system will be fully operational to monitor cargo movement (using RFID) and measure time for each process inside the Port.

\(^3\) Source : SEETO (http://www.Seetoint.org/)
iii. To develop a masterplan for rolling out the implementation of the complete version of CPMM System to the main transport corridors and routes of the Western Balkans.

The final component of this activity involves laying out the vision and roadmap for the introduction of the CPMM System in the Western Balkans. Including detailed schedules regarding the design and construction of the required database and systems, system installation, data collection, analysis and dissemination, capacity-building and outreach.

As shown in the figure below this phase of the project consisted of 5 stages. The first stage was data collection from the various relevant authorities in Bosnia and Herzegovina. The main data sources for the Project are those collected in the first phase, from the internet and from stakeholders. Received data included road networks, truck GPS coordinates, traffic detector and accident data. The second stage was data preprocessing and GIS design. The Project team operated map matching and GIS node-link design as foundation work. The third stage was the development of the performance indicators (travel time, time cost, emission, quality and reliability). The fourth stage entails analysis and development of the Prototype system. The CPMM prototype system was developed under the AWS (Amazon web service) cloud environment. The final stage involved developing a masterplan for the rollout to the rest of the Western Balkans.

Figure 2: Phase 2 development stages
2. Development and Application of the Performance Indicators

In order to develop the prototype system for measuring and monitoring rail, road and border crossing performance along Corridor Vc, a set of performance indicators had to be developed. The main selection criteria for the indicators was intuitiveness, versatility, and data availability. Based on these criteria, nine indicators in four categories were developed and presented for Corridor Vc performance measurement and monitoring purposes.

Table 1: Summary of indicators

<table>
<thead>
<tr>
<th>Category</th>
<th>Indicators</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time and reliability</td>
<td>Travel time and speed by roadways and railways</td>
<td>Average and daily vehicle travel time at the corridor roadways</td>
</tr>
<tr>
<td></td>
<td>Travel Time Index and Planning Time Index</td>
<td>Travel time between selected railway stations</td>
</tr>
<tr>
<td></td>
<td>Border Clearance time</td>
<td>Travel time reliability indicators</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clearance time of delay the average borderline crossing time.</td>
</tr>
<tr>
<td>Cost</td>
<td>Delay and delay cost</td>
<td>Total cost of delay from freight vehicles</td>
</tr>
<tr>
<td>Emission</td>
<td>Emission</td>
<td>Amounts of air pollutants (CO, NOx, PM) generated at Corridor Vc.</td>
</tr>
<tr>
<td>Reliability</td>
<td>Reliability</td>
<td>Average spot speed and the frequency rate of low speeds, standard deviation of the spot speeds</td>
</tr>
</tbody>
</table>

2.1. Time and reliability related indicators

2.1.1. Travel time indicators

Corridor Vc is a railways and roads corridor that crosses the Federation of Bosnia and Herzegovina Entity with Croatia, also only a short section in Republika Srpska. Roads carry about two thirds of the freight on the Corridor, with rail carrying the balance. This CPMM indicator focuses on both modes of transport along corridor Vc, comparing road with railway network travel time.

Truck travel time and speed

Corridor Vc is connected to the Port Ploče on the Croatian coast starting with Bosanski Šamac border crossing point in the north of the country. The total length is 400 kilometers with a traffic volume of 9,120 vehicles per day on average. Truck GPS data is one of the key data sources obtained for estimating travel time along various segments of Corridor Vc. In addition to truck
GPS data, vehicle counts from the expressway toll booth, AADT from SEETO, and the traffic volumes from the roadway detectors are also used to measure average travel time and speed.

Average travel time and average travel speed are estimated at the corridor segments using truck GPS data as follows:

\[
Truck\ Travel\ Time_{Hour,\ Link} = \frac{\sum_{l=0}^{Number\ of\ trucks} (Link\ Travel\ Time_l)}{Number\ of\ Trucks}
\]

\[
Speed_{Hour,\ Link} = \frac{Truck\ Travel\ Time_{Hour,\ Link}}{\sum Link\ Length}
\]

**Railway travel time**

The railway network along Corridor Vc is a 428 km line that connects Šamac on the Bosnia and Herzegovina side of the border to the port of Ploče in Croatia. 24% of Bosnia and Herzegovina’s cargo is transported on rail along corridor Vc, amounting to 120 million tons. Despite the team’s requests for operational and freight schedule data, relevant railway authorities did not provide the requested data, therefore, the passenger train schedule is used for estimating railway travel time. The following shows passenger rail travel times along various segments of Corridor Vc:

<table>
<thead>
<tr>
<th>Location</th>
<th>Time (min)</th>
<th>Distance (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Šamac</td>
<td>73</td>
<td>85</td>
</tr>
<tr>
<td>Doboj</td>
<td>113</td>
<td>91</td>
</tr>
<tr>
<td>Zenica</td>
<td>95</td>
<td>70</td>
</tr>
<tr>
<td>Sarajevo</td>
<td>158</td>
<td>170</td>
</tr>
</tbody>
</table>

**2.1.2. Reliability related indicators**

Travel time reliability measures are relatively new, but a few have proven effective for the specific purpose of developing indicators for the CPMM System. One of the effective measures is Travel Time Index (TTI) that compares high-delay days to those with an average delay and Planning Time Index (PTI). Other effective measures for travel time reliability would be 90th or 95th percentile travel times, or the Buffer Index. Travel time reliability related indicators used here are TTI and PTI.

**Travel Time Index (TTI)**

The TTI is the ratio of average travel time to free-flow travel time. The TTI is simply a comparison of the time it takes to travel a given segment during the peak period to the time it takes to travel that same segment under free-flow conditions:

\[
TTI = \frac{Average\ Travel\ Time}{free\ flow\ travel\ time}
\]

---

4US Department of Transportation, Federal Highway Administration, Office of Operations
Planning Time Index (PTI)

The PTI represents the total travel time that should be planned when an adequate buffer time is included. The PTI differs from the buffer index in that it includes typical delay as well as unexpected delay. Thus, the PTI compares near-worst case travel time to a travel time in light or free-flow traffic. The PTI is the ratio of the 95th percentile travel time to the free-flow travel time:

$$PTI = \frac{TT_{95\%}}{TT_{freeflow}}$$

For example, a PTI value of 2.0 means that a traveler should plan to take twice as much time to reach the destination as it would take during uncongested period. It reflects variability of travel time during a given time frame.

2.1.3. Border clearance time

Border clearance time is defined as the travel time of freight trucks at the border area. Areas of interest include the border crossing areas, inland customs, and port. Geo-fencing method is used to estimate the processing time at Nova Sela Customs. The figure below represents an example of estimating processing time at the Nova Sela border crossing area using the geo-fencing method:

- Geo fence of Nova Sela Customs consists of three zones (Zone 1: Entrance, Zone 2: Nova Sela Customs, Zone 3: Exit)
- Trip routes are created using truck GPS points from zone 1 to 3 or 3 to 1 from which travel time is estimated.

![Figure 3. Geo-fence of Nova Sela Customs](image)

- Analyze the Truck GPS data at Nova Sela Customs using data from November of 2016 (66 vehicles are monitored with 322 trips)
- Average delay at Nova Sela customs estimated at 35.3 minutes

**Figure 4. Number of freight trucks and their processing time**

- The average clearance processing time increases during the afternoon rush hour (PM 18:00~20:00)

**Figure 5. Histogram**

- 22.7% of processing times are more than 1 hour per vehicle.
2.2. Cost related indicators

Cost related indicators for trucks at specific links are defined as travel delay of the truck multiplied by the average operational cost per hour for the truck, which would be functions of the truck and driver related costs.

Truck Delay

Truck delay is defined as the difference of truck travel time and congestion threshold travel time. Speed limit of the roadway is used to estimate the truck travel time and congestion threshold travel time is used as the travel time when the truck speed is 90% of the road speed limit.

Delay per truck is estimated from truck travel time:

\[
Delay_{link} = \frac{1}{n} \sum_{i=0}^{n} (\text{Truck } TT_{\text{Hour,Link,Truck}} - \text{Cong. Threshold } TT_{\text{link}})
\]

\[
\text{Cong. Threshold } TT_{\text{link}} = \text{Cong. Threshold Speed} \times \text{link length}
\]

Where

TT : Travel Time

Cong. Threshold Speed: Congestion Threshold Speed

Truck average operational cost per hour is used to estimate the truck cost, which is a function of fuel cost, Truck/Trailer payments, repairs, insurance, licenses, tires, tolls, driver wages and benefits. In this report, 63.70 USD per hour is used to estimate the truck delay cost.5

Delay cost

\[
\text{Delay Cost}_{\text{link}} = \text{TT } Delay_{\text{link}} \times \text{Average Operational Cost per hour}
\]

Where

Average Operational Cost per Hour: 63.70 USD in US (2017)

2.3. Emissions related indicators

The EU implements the European Emission Standard system to prevent air pollution as well as enforce carbon dioxide emission regulations. Automobile emission regulations first introduced Euro 0 in 1991, followed by a series of revisions up to the introduction of Euro 6 in September 2014. All new vehicles must meet Euro 6 standards by September 2015. The emissions regulated by Euro 6 are carbon monoxide (CO), bullet hydrogen (THC), non- methane hydrocarbons (NMHC), nitrogen oxides (NOx) and soot particles (PM). We estimate emissions from CO, NOx and PM.

---

The Intergovernmental Panel on Climate Change (IPCC) classifies methodological approaches to estimating emissions in three different Tiers. Tier 1 methodology uses fuel as the activity indicator, in combination with average fuel-specific emission factors. Therefore, the Tier 1 method should only be used in the absence of any more detailed information than fuel statistics. Tier 2 is similar to Tier 1, but more specific to the country’s emission factors. Tier 3 is the most advanced Methodology which is what we use for the purpose of developing the CPMM System.

Table 2. IPCC Tiers for estimating emissions\(^6\)

<table>
<thead>
<tr>
<th>Tier</th>
<th>contents</th>
</tr>
</thead>
</table>
| Tier 1 | Tier 1 employs the gain-loss method described in the IPCC Guidelines and the default emission factors and other parameters provided by the IPCC.  
• data on the amount of fuel combusted  
• a default emission factor (e.g. provided by the IPCC). |
| Tier 2 | Tier 2 generally uses the same methodological approach as Tier 1 but applies emission factors and other parameters which are specific to the country.  
• data on the amount of fuel combusted  
• a country-specific emission factor for each gas. |
| Tier 3 | In the Tier 3 method described here, exhaust emissions are calculated using a combination of firm technical data (e.g. emission factors) and activity data (e.g. total vehicle km). |

The key input variables are vehicle speed, acceleration measurements and vehicle technology data. Technology data includes vehicle type, vehicle category, and engine type are used with appropriate assumptions.

**Performance measures of emission Indicators**

In the following Tier 3 approach, total exhaust emissions from road transport are calculated as the sum of hot emissions (when the engine is at its normal operating temperature) and emissions during transient thermal engine operation (termed ‘cold-start’ emissions).

\[
E_{total} = E_{hot} + E_{cold} \quad \text{(i)}
\]

where,

- \(E_{total}\) = total emissions (g) of any pollutant for the spatial and temporal resolution of the application
- \(E_{hot}\) = emissions (g) during stabilised (hot) engine operation
- \(E_{cold}\) = emissions (g) during transient thermal engine operation (cold start)

\(^6\) IPCC Tiers and EMEP/EEA(2016) Road transport
Total emissions are calculated by combining activity data for each vehicle category with appropriate emission factors. The emission factors vary according to the input data (driving situations, climatic conditions). The basic formula for estimating hot emissions for a given time period, and using experimentally obtained emission factors, is:

\[
\text{emission [g]} = \text{emission factor [g/km]} \times \text{number of vehicles [veh]} \times \text{mileage per vehicle [km/veh]} \quad (\text{ii})^7
\]

\[
\text{emission factors (EF)} = \frac{(\text{Alpha} \times V^2 + \text{Beta} \times V + \text{Gamma} + \text{Delta} / V)}{(\text{Epsilon} \times V^2 + \text{Zeta} \times V + \text{Hta}) \times (1 - \text{RF})} \quad (\text{iii})^8
\]

where,

\[ V = \text{speed} \]
\[ \text{RF} = \text{reduction factor} \]
\[ \text{Alpha, Beta, Gamma, Delta, Epsilon, zeta, Hta} = \text{EMEP/EEA’s factor} \]

In terms of estimation of CO2, NOx, PM from trucks on corridor Vc, emission factors are provided for conventional vehicles and the Euro 1 to Euro 6 emission standards. Three assumptions are made to calculate emissions from trucks operating along Corridor Vc:

I. Estimation of only Hot emissions

II. Categorized by two vehicle types (Rigid 7.5-12t and Rigid 20-26t)

III. Categorized by EURO 3

Using tier 3 methods based on the three assumptions above, we estimated a sample truck’s emissions on corridor Vc. The emissions for the month of October 2015 are as follows:

---

7 EMEP/EEA air pollutant emission inventory guidebook 2016
8 EMEP/EEA air pollutant emission inventory guidebook 2016
2.4. Quality related indicators

In addition to trucks’ travel speed, the spot speeds in truck GPS data can be used to measure corridor performance. Three indicators are measured in the CPMM System which is average spot speed, frequency rate of low speeds, speed/predictability:

- Average spot speed and the frequency rate of low speeds are used to locate and measure the severity of the bottlenecks.
- The standard deviation of the spot speeds is employed to quantify the predictability of the corridor traffic condition.
By combining the speed measure and predictability measure, the corridor segments are categorized as follows:

- **Low speed – low predictability**: This is a characteristic of corridor segments with typically low speeds, but with varying degrees of congestion that consequently result in large variation in travel times.
- **Low speed – high predictability**: This category can be assigned to the corridor segments that experience constant congestion. While the speed level is low, there is a certain degree of predictability in travel times.
- **High speed – low predictability**: The traffic condition on such corridor segments is considered to be moving relatively fast or close to free flow, but the segments are also prone to unexpected delays.
- **High speed – high predictability**: The corridor segments of this category are in good and reliable traffic condition.

### 2.5. Interactive Report Screen Captures

Figures 9-15 below, present interactive report screen captures from the CPMM System for key indicators such as travel speed, traffic volume, costs, and emissions.

![Figure 9. Travel Speed Report Configuration](image-url)
Figure 10. Traffic Volume Report Configuration

Figure 11. Cost related indicator Report Configuration
Figure 12. Emission related indicator Report Configuration

Figure 13. City to City travel time Report Configuration
Figure 9 shows that the delay happen at the border crossings in the south and the north. Figure 14 shows that the TTI is more or less uniform along the corridor—with travel time at the peak hour taking about 40 percent more than it would take in free flow conditions.
Rail data obtained so far is very limited and with no time dimension. Therefore, rail data are summarized as a dashboard rather than an interactive report.

Figure 155. Rail Dashboard Report Configuration
3. Design and Development of the CPMM System

3.1. Data and methodology

During Phase 1 of this activity, historical data for 2014-2016 was requested and received from the relevant authorities. During the kickoff meeting for phase 2, historical data for 2016-2017 was evaluated, requested and received to further develop the CPMM System. New indicators were developed using two sets of the traffic data: available GPS data from number of vehicles using Corridor Vc and traffic counters data from Road authorities. Details of data sources used can be found in annex 1 and described in detail in the phase 1 report, therefore will not be repeated here.

One of the major challenges of integrating collected data on road characteristics and road events was to establish data/information depository, which is currently not existent at the national level in BiH. The data is collected by multiple agencies without having common interoperability standards or established data exchange procedures. Development of flexible and replicable Data model for the CPMM system is essentially required in support of cross referencing data in the complete CPMMS.

In terms of methodology to developing the CPMM System prototype, the following two main approaches were employed:

3.1.1. Map-matching method

The main purposes of map matching are to build each vehicle’s trip along the path, generate the link travel time and speed from each trip and remove the inappropriate data.

Three main algorithms are available for map-matching. First, the geometric method which focuses on the distance between the position and the candidate road links, and the similarity between the road links and trajectory by projective. This method is a common map-matching method that is simple to apply. Second, the topological method which considers both geometrical data and topological relationships of trajectory by positions and candidate road links as the decision factors. Third, the probabilistic method which focuses on all position data and all candidate road links instead of calculation between individual positions and nearby links from the initial match. This is the approach used in developing the CPMM System, which has more link matching accuracy than the first and second methods.
When using GPS data to quantify link performance, the exact link speed and the number of vehicles are critical. Probabilistic map matching methods are good at generating link information with GPS point data. It is possible to calculate the exact number of links even if there are no or double GPS points in the link. Map matching methods are powerful in calculating link speeds as well as in number of links. As shown in the figure, only one of the six links has correct link speed and the remaining links are miscalculated. The map matching method we perform tracks GPS points. It is therefore useful to calculate the correct link speed.

In developing the CPMM System, we employ the map matching method using real-time routing engine with Open Street Map (OSM) data (Europe region). OSM data is converted into the routable OSM network using OSM convert and OSM filter library. We also use the Hidden Markov Model (HMM) for map matching. Steps for the HMM based map matching:

- Step 1: Use the information from all trajectory points
• Step 2: Choose the most likely path through the road network given the available position estimates.

The transition probability is calculated using the shortest path routing between each pair of candidate roads. HMM-based map-matching for GPS position – one of probabilistic methods are chosen for the project. Map matching are to associate a sorted list of user or vehicle positions to the road network on a digital map.

Map matching results from a sample trajectory ID 50879 on Nov. 2016 are shown below. We matched the GPS data to a link in corridor Vc and were able to express the exact link attribute.
The table below shows results from map matching (original GPS point trajectory to Node-Link data with properties).

<table>
<thead>
<tr>
<th>Matchings index</th>
<th>Step ID</th>
<th>Start Node</th>
<th>End Node</th>
<th>Link Distance (meter)</th>
<th>Duration (sec)</th>
<th>Speed (m/sec)</th>
<th>Speed (Km/h)</th>
<th>GPS Time</th>
<th>GPS Speed</th>
<th>In Time</th>
<th>Out Time</th>
</tr>
</thead>
<tbody>
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<td>55.00</td>
<td>-</td>
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</tr>
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<td>3731766381</td>
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<td>5.33</td>
<td>19.13</td>
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<td>16</td>
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<td>2016/11/01 09:02:42</td>
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<td>14556546554</td>
<td>13.60</td>
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<td>5.93</td>
<td>21.33</td>
<td>2016/11/01 09:02:42</td>
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<td>8.40</td>
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<td>16</td>
<td>2016/11/01 09:02:44</td>
<td>2016/11/01 09:02:52</td>
</tr>
</tbody>
</table>

Figure 20. Map matching results Sample

Figure 211. Map matching result

3.1.2. Geo-fencing method

Another methodology employed in developing the CPMM System is Geo-fencing where a virtual fence or a perimeter around a physical location is created to estimate the border crossing time
using truck GPS data. The border crossing time is estimated from Enter and Exit GPS points from the same vehicles that are located at each geo-fence of the border.


**Figure 22. Geofence**

Using the geo-fencing method for estimating border crossing time, two virtual Geo-fences (Geo-fence A and B) were created at each side of the border. All truck GPS databases are plotted on the map and two GPS points are selected from each Geo-fence, which has the same vehicle ID and timestamps, identifying the same trip a truck made from A to B or B to A. The difference between these two time-stamps is used to estimate the border crossing time.

### 3.2. System Architecture Design

The CPMM System is developed under the AWS (Amazon Web Service) cloud environment. The AWS system architecture is designed and deployed as shown in Figure 19:

1. 3-tier server architecture is adopted and redundant servers are applied for reliability.
2. The 2-year truck GPS data and traffic volume count data are processed for the defined performance indicators. The processed data and the indicators are stored in AWS RDS (Relational Database Service) DB tables.
3. To guarantee the proper system performance for global and/or widearea service, AWS CLOUDFRONT, the CDN (Contents Delivery Network) service, is applied to the system.

Other optional instances can be employed as desired:

- Low-cost storage S3 may be adopted to store the infrequently-used raw data in cost-effective manner.
- To enhance system security and reliability, other optional items -shown as green icons in <Figure 19>- may be employed as desired.

---

Three levels of GIS layer for the Corridor Vc was designed and developed (Figure 24):

1. Level 0 between OSM nodes was defined but is only used for internal purposes.
2. Level 1 is defined as the roadway link with homogeneous geometric characteristics and similar traffic flow conditions. For the homogeneity and similarity, the corridor is segmented as level 1 links with the following principles:
   a. Split roadway sections where speed changes are expected.
   b. Split the links where freeway with ramp or traffic signal at the roadway
   c. Split the links where delay time calculations are required within the major cities
   d. Split the links at the port area, border crossing and customs area to estimate the special processing times

3. Level 2 is defined as inter-city links, which present city-to-city corridor performance. In the CPMM System, the cities dividing the corridor as level 2 links includes Ploče, Mostar, Sarajevo, Zenica, Doboj, Slovonski Brod.

When the geographic scope of the system is expanded to a multi-corridor network, the whole corridor should also be defined as Level 3 to measure performance along the entire corridor and compare performance among other corridors of the network. When measuring the time spent at
ports, inland customs, and border crossings, separated from this GIS layers, geo-fence method is applied.

![Figure 244. GIS layers for the corridor Vc](image)

3.4. **Data providers for the system**

The table below shows the data providers for Corridor Vc. Similar providers will be necessary for the other corridors and routes.

<table>
<thead>
<tr>
<th>Public Institutions</th>
<th>Data Provider</th>
<th>Agency/Organization Name</th>
<th>Data requested</th>
<th>Data received</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Roads and Highways Authorities</strong></td>
<td>Public Company Roads of Federation of Bosnia and Herzegovina (JP Ceste Federacije BiH)</td>
<td>Road class; road ownership; road parameters; road condition; traffic volume; design speed and speed limits; location of toll-plazas and roadside service facilities; location and number of road accidents; road centerline –GIS; start/end coordinates for each road section</td>
<td>Road class; road ownership; road parameters; traffic volume; design speed and speed limits; road centerline –GIS; start/end coordinates for each road section</td>
<td></td>
</tr>
<tr>
<td>Public Company Roads of Republika Srpska (JP Putevi Republika Srpska)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Identified data providers
<table>
<thead>
<tr>
<th><strong>Motorways of Federation of Bosnia and Herzegovina</strong>&lt;br&gt;<strong>Motorways of Republika Srpska Roads (JP Autoputevi Republika Srpska)</strong></th>
<th><strong>Motorways of Republika Srpska Roads (JP Autoputevi Republika Srpska)</strong></th>
<th><strong>Road class; road ownership; road parameters; traffic volume; design speed and speed limits; start/end coordinates for each road section</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Traffic Police</strong>&lt;br&gt;Traffic Police Federation BiH&lt;br&gt;Traffic Police Republika Srpska</td>
<td>Location and number of road accidents; their category and reason of occurrence.</td>
<td>Location and number of road accidents</td>
</tr>
<tr>
<td><strong>Border Police</strong>&lt;br&gt;Border Police BiH&lt;br&gt;Border Police Croatia</td>
<td>Volume of passengers; traffic volume; time for completing transit procedures; volume and value of goods.</td>
<td>Volume of passengers; traffic volume in BiH</td>
</tr>
<tr>
<td><strong>Customs Authority</strong>&lt;br&gt;Customs BiH&lt;br&gt;Customs Croatia</td>
<td>Time for completing export and import procedures on selected customs terminals disaggregated by group of goods, procedure, value and volume, 2014-2016</td>
<td>Time for completing export and import procedures on some of the selected customs terminals disaggregated by group of goods, 2016; volume and value of goods imported and exported by selected customs terminals</td>
</tr>
<tr>
<td><strong>Port Authority</strong>&lt;br&gt;Port of Ploče</td>
<td>Type and volume of goods; port procedures; average process time per year for the procedures (import, international transit and domestic transit and export) per customs office disaggregated by type of goods</td>
<td>Port procedures; average process time per year for the procedures</td>
</tr>
<tr>
<td><strong>Vehicle tracking systems</strong>&lt;br&gt;Automatic tracking system solution providers</td>
<td>GPS coordinates and time stamps for selected vehicles;</td>
<td>GPS coordinates and time stamps for selected vehicles;</td>
</tr>
<tr>
<td>External</td>
<td>Auto moto clubs</td>
<td>BIHAMK Auto-moto Club Bosnia</td>
</tr>
<tr>
<td>---</td>
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<td>---</td>
</tr>
<tr>
<td>Regional Transport Observatory</td>
<td>SEETO/The Transport Community Treaty</td>
<td>Road section details (condition and capacity); traffic volume</td>
</tr>
<tr>
<td>International Development Bank</td>
<td>WB</td>
<td>IDs of enterprises located within the buffer zone of Corridor Vc</td>
</tr>
</tbody>
</table>

For more information on data providers, see World Bank Report (June 2017): The Western Balkans, Benchmarking Corridor Performance: A Pilot for Corridor Vc in Bosnia and Herzegovina.
4. Developing a Master Plan for the CPMM System

4.1. Scaling-up the CPMM System Prototype to the Western Balkans: A mid-term Master Plan

The cost of addressing trade and transport related impediments in the Western Balkans region is roughly estimated at €8,140 million\(^{10}\), which is about 5% of the total GDP of the six Western Balkans countries 11 plus Croatia for the period 2014-2020. This amount which covers both physical interventions and “soft” measures, creates a large financial burden on the budgets of the governments of these countries and therefore requires the development of a priority project pipeline that reflects the economic and social benefits and that is aligned with available financial resources from national governments, the EU and the private sector.

One of the key objectives of the CPMM System is to provide the countries of the Western Balkans with a tool that can help identify priority corridors and routes based on objective data and performance evaluation. It also aims to increase accountability, transparency, effectiveness and efficiency of investment planning and policy-making related to transport corridors and networks in the Western Balkans. It, therefore, becomes essential to scale up the CPMM prototype to rest of the Western Balkans. In order to achieve a successful rollout a detailed master plan needs to be developed.

The key objective of the master plan is to make a strategic regional plan for the implementation of CPMM in the Western Balkans. The detailed roadmap provides the vision for the introduction of the CPMM and its rolling out to different corridors and routes on the regional network; and a time-bound action plan for Corridor Vc that includes detailed schedules regarding the design and construction of the required database and systems, system installation, data collection, analysis and dissemination, capacity-building, outreach, etc. It also includes institutional, legal and financial elements needed for implementation and recommendations for the use and institutionalization of the TDMS in transport policies.

The master plan for the intelligent CPMM System is the first comprehensive and systematic plan for the Western Balkans region to access the performance of corridors and routes and track progress in improving the quality and reliability of travel. It is a medium-term plan for the integrated management and operation of traffic data collected from major transport corridors and networks of the entire Western Balkans region.

The master plan aims to develop a multimodal transport corridor monitoring system over the course of five years to maximize data usage by linking and integrating a systematic and efficient transport data management system including all roads and transport network in the Western Balkans. The master plan aims to provide a comprehensive and systematic plan to support the

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10 The estimate is for 2016-2020. See for more details REBIS Update, 2015.
11 Albania, Bosnia & Herzegovina, Kosovo, the former Yugoslav Republic of Macedonia, Montenegro and Serbia.
investment planning and policies in comprehensive consideration of stakeholders such as policy makers and private sector participants.

4.2. Key characteristics of the Master Plan and scope of work

(i) Time Scope

- Total plan period: 2019-2023 (5 years)
- Time Plan by Phases
  - Stage I: 2019-2021 (2.5 year)
  - Stage II: 2021-2022 (1.5 years)
  - Stage III: 2023-2023 (1 year)

<table>
<thead>
<tr>
<th>Year</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase</td>
<td>Stage I</td>
<td></td>
<td>Stage II</td>
<td></td>
<td>Stage III</td>
</tr>
</tbody>
</table>

(ii) Spatial Scope

The spatial scope is divided into 3 stages. Stage I targets the major corridors in the Western Balkans, and the stage II covers the major routes, airports and sea ports. In the third and final stage, the master plan covers comprehensive routes and inland waterways. The spatial scope of each stage in the master plan is as follows.

- Stage I: Major corridors and railways in the Western Balkans
  - Major corridors include Vc, Vii, X, Xb, Xc and Xd
  - Major railways include Vc, Vii, X, Xb, and Xc
- Stage II: Major routes, railways and airports and sea ports in the Western Balkans
  - Major routes include 1, 2a, 2c, 4 and 7.
    - Major railways include 2, 4 and 9a
    - Airports and Sea Ports
- Stage III: Comprehensive routes and inland waterways ports in the Western Balkans
  - Comprehensive routes include 2b, 3, 5, 6b and 9a.
  - Inland Waterways Ports
(iii) **Scope of Contents**

- Data standardization and exchange protocols established
- Development of corridor performance measurement and monitoring system
- Development of performance indicators and multi-modal integration
- Regional expansion of the prototype for the CPMM System

4.3. Strategies for Master Plan Development

1) **Efficient operation and management of the transport system**

The CPMM collects traffic information in real time (dynamic data) using GPS and driver’s report, provides traffic conditions and congestion information, improves mobility of the corridors and networks as a result of faster emergency detection and response at the Traffic Information Center, and thus maximizes efficiency of the corridors and networks.
2) **Decisions Support for priority investment**

The CPMM collects infrastructure data (static data) from institutions to identify condition and locate causes of bottleneck. It provides a basis for selecting priority investment in regional infrastructure in the Western Balkans and ensures closer integration with the EU.

3) **Accident reduction by improvement of road transport safety**

The CPMM enables fast emergency detection/response/information service from the Traffic Information Center using CPMM to prevent secondary accidents, facilitates fast cooperation among relevant agencies, thus improving road safety.

4) **Mobility enhancement by improvement of transport and logistics functions**

The CPMM collects and provides accurate traffic information to improve mobility along corridors and networks and help drivers make more informed decisions regarding choice of routes.

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**Figure 266. Strategies for Master Plan**

4.4. **Consideration and Selection of Promotion Projects**

The process of selecting promotion tasks from the master plan follows the following order: status analysis, vision and goals setting, drawing of promotion tasks, selection of priority order and selection of key promotion tasks.
In the status analysis phase, the current status of transport is analyzed and issues pertaining to regulations and institutions, status of roads, airports, sea ports, inland waterway ports and analysis of relevant transport systems of advanced countries are presented.

In the second phase, "Realization of Efficient, Effective, Safe and Comfortable Corridors in the Western Balkans by Implementation of the Cutting Edge Intelligent Transport Management System" is set as the vision and goals, and strategies are presented to specify the basic direction of promotion tasks.

In drawing of promotion tasks, the basic direction of promotion tasks and considerations for drawing tasks are defined and appropriate promotion tasks are drawn. The standard for selecting the priority order of drawn promotion tasks is presented and the priority order for investment is selected.

Finally, in selection of key promotion tasks, goals for each task are set and a detailed roadmap is prepared by considering previously drawn promotion tasks and the priority order for investment:

i. Interface with the data sources in the Western Balkan countries:

Connect with public data sources in Western Balkan countries: Road authorities from each country collecting traffic data (mostly traffic volume and speed) would be incorporated with the CPMM through the following steps:

- Carry out consultative workshops in each country with public and private sector stakeholders
- Propose the standard interface for data acquisitions and define National access point\(^{12}\)
- Retrieve traffic data from public traffic operation systems in each country
- Relevant agencies in each country
  - Roads: roadway planning and operation offices (ITS centers)

\(^{12}\) For dynamic data, machine-readable format compatible and interoperable with defined standards and technical specification of the system (EU ITS directive and DATEXII for data standards.) For static data, API that provide access to data from national system (e.g. RAMS) via defined national point (based on EU directives for infrastructure data) For Spatial data – INSPIRE EU Directive
- Railway: Regional operation centers
- Accident data (police)
- Border Police
- Customs Offices and Terminals
- Port Authority

**Establish connections with private data sources:** Data companies in these areas would be surveyed and contracted as following steps.

- Survey the candidate companies and their data availabilities
- Procure the private data from the markets as necessary
- Candidate data
  - GPS data from freight vehicles
  - Cell phone data from mobile companies
  - Navigation data from Navigation Companies

**Develop data connection procedure:** With agreements with the data authorities in place, the interface will be developed with data connection procedures. All the connections will be documented and developed for each step.

- Design the steps and procedures based on the agreement with data sources
- Develop and implement standard protocol
- Retrieve the data from the remote systems
- Verifying the data internally
- Import data to the local database system

**ii. Design of the CPMM data model and architecture**

Design and develop the database and its operation system

- Design the database: data type, domain and their codes
- Design and implement the database applications: data flow and operations for each application
- Develop the data managements and operation procedures

**iii. Develop CPMM internal services and operations**

- Develop the data management and the operation procedures for the data center
- Implement ETL procedures: Define and develop the ETL (Extract, Transform and Load) process for the input data
• Develop the procedure to integrate the traffic data from the different regions/countries
• Develop the procedure to integrate the traffic data from the different data sources

iv. Development of the CPMM applications and statistics

➢ Develop and maintain the maps
➢ Design and develop the traffic indicators
  • Review the traffic indicators with stakeholders
  • Develop the indicators with the following criteria
    - Traffic modes (Roadway/railway/port/air)
    - Traffic data types (Passenger/freight)
    - Regions (Country- or corridor-specific)
    - Performance and safety
➢ Develop traffic reports
  • Develop and verify the basic reports for each indicator
  • Develop the interface for the web and paper format
➢ Receive and incorporate feedback from stakeholders

v. Expansion of the CPMM system functions

• Develop the open data API for public access: Allow the public to access the archived CPMM data for other applications
• Proliferation of the CPMM with external systems: Allow the CPMM to be extended with other systems to produce additional data or reports
• Extension of the system with other systems (Logistics, integrate with real time traffic monitoring system): Allow the CPMM results to be integrated or embedded with the external systems.
• Convert into the real-time system: Design and develop the CPMM as the real-time ready system and convert it into real-time traffic monitoring system if appropriate

Figure 18 below shows a technical roadmap for the promotion of the CPMM system in the Western Balkans. Looking at the roadmap strategically, it entails adding modules to the system developed for Corridor Vc, extending it to other corridors and then converting the current system into a real-time system. The focus of Stage 1 (2019-2021) will be on carrying consultations with public and private sector stakeholders to explain how they can benefit from
the system, to seek their commitment to providing the required data. Stage 1 also entails establishing connections with private data providers. Stage 2 (2021-2022) and Stage 3 (2023) continue the work under Stage 1 but with an increased focus on adding modules, connecting to other systems and converting the system into a real-time system.
Figure 288: Roadmap of Promotion Projects for Master Plan

Stage 1

**2019**
- Connect with public data sources in Western Balkan countries
  - Establish the connections with private data sources
  - Develop the data connection procedure

**2020**
- Develop the database and its operation system
  - Develop the TDMS services and operation
  - Implement ETL procedures: Define and develop the ETL (Extract, Transform and Load) process for the input data

**2021**
- Maintain the maps
  - Design and develop the traffic indicators
  - Develop the traffic reports
  - Apply feedbacks from the stakeholders

**External Interface**

**TDMS data design**

**TDMS operation**

**TDMS Application**

**Expansion of TDMS**
Table 4. Identified data providers Estimated Project Cost

<table>
<thead>
<tr>
<th>Steps</th>
<th>Tasks</th>
<th>Budget (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Stage 1 (30Months)</td>
</tr>
<tr>
<td>Interface with data sources</td>
<td>• Connect with public data sources in Western Balkan countries</td>
<td>300K</td>
</tr>
<tr>
<td></td>
<td>• Establish the connections with private data sources</td>
<td>200K</td>
</tr>
<tr>
<td></td>
<td>• Develop the data connection procedure</td>
<td>500K</td>
</tr>
<tr>
<td>Design of the TDMS data model and architecture</td>
<td>• Develop the database and its operation system</td>
<td>300K</td>
</tr>
<tr>
<td>Develop the TDMS internal services and operations</td>
<td>• Develop the TDMS services and operations</td>
<td>200K</td>
</tr>
<tr>
<td></td>
<td>• Implement ETL procedures: Define and develop the ETL(Extract, Transform and Load) process for the input data</td>
<td>150K</td>
</tr>
<tr>
<td>Development of the TDMS applications and statistics</td>
<td>• Maintain the maps</td>
<td>30K</td>
</tr>
<tr>
<td></td>
<td>• Design and develop the traffic indicators</td>
<td>120K</td>
</tr>
<tr>
<td></td>
<td>• Develop the traffic reports</td>
<td>100K</td>
</tr>
<tr>
<td></td>
<td>• Apply feedback from the stakeholders</td>
<td>100K</td>
</tr>
<tr>
<td>Expansion of the TDMS system functions</td>
<td>Sub total</td>
<td></td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>-----------</td>
<td>---</td>
</tr>
<tr>
<td>• Develop the open data API for public access</td>
<td>100K</td>
<td>50K</td>
</tr>
<tr>
<td>• Proliferation of the CPMM with external systems</td>
<td>100K</td>
<td>100K</td>
</tr>
<tr>
<td>• Extension of the system with other systems</td>
<td>100K</td>
<td>100K</td>
</tr>
<tr>
<td>• Convert into the real-time system</td>
<td>500K</td>
<td>300K</td>
</tr>
<tr>
<td><strong>Sub total</strong></td>
<td><strong>2.0M</strong></td>
<td><strong>1.62M</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4.9M</strong></td>
<td></td>
</tr>
</tbody>
</table>
Conclusion

As the second phase of the project, the corridor performance measurement and monitoring project for the Corridor Vc in Bosnia and Herzegovina was carried out with the objectives to develop the corridor performance indicators, to develop the prototype and to generate the master plan in the Western Balkans corridors. While phase 1 of this activity was carried out to prove the utility of data acquired and initial analysis, phase 2 built on this to successfully prove the usefulness of the traditional transportation data management system using new trends - big data analysis in transportation and web-based system implementation using cloud system.

The corridor performance indicators are general outputs of the traditional traffic data management system and require data feeds from the traffic detectors on the roadway, incident reports from the police, operation data from the railways, etc. In this phase, the truck GPS data on the Corridor Vc are used to develop the traffic indicators to replace the traditional traffic counts on the roadways. Nine indicators from four categories are developed and presented in the prototype, which are:

- Travel time and speed by roadways and railways
- Travel Time Index and Planning Time Index
- Border Clearance time
- Delay time and delay costs
- Emission
- Reliability

The CPMM System prototype that was developed in phase 2 demonstrates how Big Data can be utilized to produce the key performance measures on Corridor Vc. Traffic data from truck GPS equipment illustrates the possibilities to replace traditional traffic detectors on roads and successfully produce traditional traffic indicators.

The prototype system is developed using the Amazon Web Cloud System, which shows the full benefits of web-based systems development: easy system configuration and expansion, handy development environment, and convenient and affordable maintenance.

In chapter 4, the master plan for the corridor performance monitoring and measurement system presents its objectives and goals, vision and requirements. It provides not only simple expansion of the prototype, but also the proposal for the sustainable system from the data source issues to the final goal of the CPMM System. The real-time traffic monitoring system with open architecture, which can easily be merged into or integrated with other systems would be the vision for the full scale system representing not only Corridor Vc but all corridors and routes in the entire region of the Western Balkans.
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