ROAD MAPS FOR URBAN MOBILITY

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ABSTRACT

The exploring for new possible solutions to the societal problems, such as sustainable mobility, demand that the focus of the studies been in the desirable images of the future. For this scenario planning and backcasting methodologies are useful methods as they can help to build future scenarios and define the pathway or road maps to achieve them. In this sense the objective of this paper is to propose a methodology for the development of road maps for the urban mobility sector that will be validated by the development of a case study applied to some cities of Kazakhstan, an Asian country.

Keywords: Road Map, Urban Mobility

INTRODUCTION

The exploring for new possible solutions to the societal problems, such as sustainable mobility, demand that the focus of the studies been in the desirable images of the future. For this scenario planning and backcasting methodologies are useful methods as they can help to build future scenarios and define the pathway or road maps to achieve them. The result of such planning exercise, the road maps, are valuable tool that can help investors to address the scarcity of information in the urban mobility sector and in the region under consideration, which could lead to excessive improvisation; shape the investors internal thinking on this sector, in particular by helping bridge the gap between operational and strategic thinking.

In this sense the objective of this paper is to propose a methodology for the development of road maps for the urban mobility sector that will be validated by the development of a case study applied to some cities of Kazakhstan, an Asian country. The paper is structured in five sections starting by this introduction. Section 2 presents a brief literature review regarding scenario building methods and backcasting approach. Section 3 contains the detailing of the methodology proposed. Section 4 refers to the case study application. Finally, section 5 presents the main conclusions derived from this planning exercise.

LITERATURE REVIEW

Nowadays long forecasting studies are concerned not so much with what will happen in the future, but mainly with what could or should happen in the future. According to Höjer and Mattsson (2000) these kind of studies have two different purposes. The first is related with the desire to know what will happen in the future (possible and probable future) in order to make adjustment while there is still time. The second is related with the belief that actions can be taken in order to shape the development (desirable future).

There are a variety of approaches and techniques to support the development of future studies such as modeling, forecasting, scenario building, backcasting, delphi studies, casual analysis, etc. Each one of these approaches and techniques has a specific role and is used to perform different functions. However, they do not oppose each other, in fact some approaches can be seen as a supplement of others and the combined use of different techniques provide a more robust support to the decision makers.

From the set of available approaches and methods, scenario building and backcasting are the ones most suitable when the purpose is to achieve overarching goal such as the ones linked to a sustainable future. According to Garcia et al (2010), the aim in a scenario building exercise is to develop distinctive, divergent images of the future. Typically, scenarios are not specified by a quantifiable set of variables, rather they are storylines that describe the state of the main drivers and local factors and how they are interrelated. These storylines are descriptions of how driving forces states manifest in the local context and are considered as alternative futures realities and not as different outcomes of the same reality (Wack, 1985).

Scenarios studies can be categorized as predictive, explorative and normative (Börjeson et al., 2006). Predictive studies dealing with probable futures and try to answer the question *What will happen?* using forecasting models and trend analysis. Explorative and normative studies in turns are the ones focused on possible and desirable futures respectively and are interested in answer the questions *What could happen?* and *How a specific target can be reached?* Carlsson-Kanyama et al. (2008) describe the difference between explorative and normative scenarios by applying the concepts of push and pull driving forces, where push corresponds to a causal analysis and pull to a teleological analysis.

Backcasting in turn is an approach that works backwards from an envisioned scenario to the present situation, consisting of a rule-based analysis and resulting in normative policies in order to achieve the desired goals (Haslauer et al., 2012). Dreborg (1996) consider that the backcasting method is more suitable to deal with long-term complex issues, involving many aspects of society as well as technological innovations and change. For him the focus of interest in this kind of approach is on a perceived societal problem of great importance such as the vast and growing impacts of the transport sector on the environment.

There is a variety of literature relating to backcasting methodologies applied to transport field (Dreborg, 1996; Geurs and Van Wee, 2004; Åkerman and Höjer, 2006; Hickman and Banister, 2007). However in general a backcasting process works as depicted in Figure 1.

It starts by setting one or a few long-term targets, and then each target is evaluated against the current situation, prevailing trends and expected developments. Following images of the future or envisioned scenarios that fulfill the target are generated. Finally the scenarios are analyzed in terms of feasibility and paths towards the images are developed (Höjer and Mattsson, 2000).

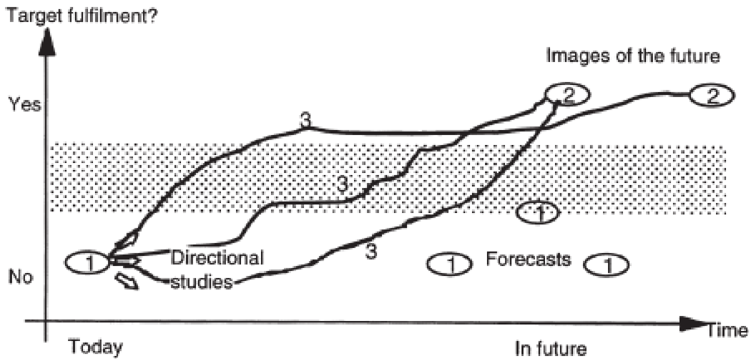

Figure 1 Backcasting process. (Höjer and Mattsson, 2000).

Although some authors consider that the forecasting and backcasting methods are oppose (Roth and Kåberger, 2002), others look at them as complementary. Höjer and Mattsson (2000) argue that backcasting is dependent on forecasts as it serve as way to indicate that the targets which have been set will not be attained. If this is the case, alternatives scenarios that meet the targets are defined and the consequences of the scenarios in various respects and the drives that may influence their realization are analyzed.
The current methodology presented in this paper is consistent with this latest approach, where backcasting results from an iterative process that evaluates the results of a forecast under a scenario of input variables and policies that may impact the system layout (infrastructure) and the behavioral reaction of society to the structural changes produces (i.e. new transport alternatives, changes in travel times or travel costs, etc.).

METHODOLOGY

The proposed Urban Mobility Road Map methodology consists in four steps structured as following:

1. **Assessment** and **benchmarking** of the status quo of the country sector and governmental development plans for Urban Mobility.
2. Development of a **vision** for the future of the sector in the country and its translation into a set of **policies** tested over a group of **scenarios**.
3. **Forecasting** sector demand and needs in these scenarios.
4. **Backcasting** from the desirable scenarios to calculate implementation capital and financial needs and other policy and program requirements. This step requires de use of impact indicators to assess the achievement of the **vision** at the time horizon.

The first step, assessment and benchmarking is the starting point for the methodology and consist in two components: the assessment of the current situation in the sector to set a baseline scenario and a benchmarking analysis in order to estimate how the main parameters may evolve with the change of the exogenous variables (population and GDP). This phase encompasses the analysis of supply, demand, commercial, regulatory and social aspects.
The second step, the vision and scenario development, follows the factual assessment of the current situation and a vision will be compiled. A vision is a semi-quantitative set of hypotheses for the development of a particular sector. This element should contain the

definition of policy targets that want to be achieved at the time horizon of the analysis, that should be designed taking into account the country strategic guidelines and world trend in the corresponding sector.

The set vision is then tested against a set of scenarios of the exogenous variables, which are generated from a decision trees that encompasses the main variables that may trigger different policies for the selected vision. Scenarios are also means of exploring the implications of extreme combinations of design parameters to ascertain the performance boundaries of the system and to provide a quantification of the uncertainty associated to the vision, particularly for long-term timeframes, by exploring the consequences of departures from a sensibly posed set of assumptions (Zegras et al., 2004).

The third step is the forecasting. As the Road Map is essentially quantitative, it is based on the use of mathematical models for quantifying the implications of the vision and scenarios. The output of the forecast is a detailed picture of the sector for the present mobility and for the corresponding time horizon for the base scenario. Several indicators are computed to quantify the performance of different components of the system, providing a compact, objective way of comparing alternatives. The indicators span economic, societal and environmental aspects.

Backcasting is the fourth step. It is the process through which quantified output data from a scenario are used to calculate present-day capital and financial needs, as well as other policy and regulatory requirements. The backcasting exercise will give snapshots at several time horizons, e.g. T+5, T+15, T+30. This is an interactive process until the policies tested achieve the goals of the vision.

The final product of this process is the establishment of a **pathway** from today to the **vision** or a **road map** that can serve investors to persuade national governments to adopt specific strategies and to establish financing priorities.

In order to assess the urban mobility impacts under a sustainable development framework, a set of indicators was developed. These indicators are:

1. **Congestion costs.** The congestion costs were estimated by multiplying the estimated value of time by the difference between saturated time and empty time. The estimation of the evolution of the value of time was modeled using a discrete transport mode choice model calibrated for the city of Lisbon (Eiró and Martinez, 2012). The obtained value of time from this study was then indexed to the GDP per capita, allowing an easy update of this unit cost. This elasticity was obtained through a study that surveyed several countries and developed a discrete choice model, obtaining a value of time elasticity to GDP per capita variation of 1.79% (Zamparini and Reggiani, 2007).

2. **Fuel technology and CO_2 emissions.** The CO_2 emission coefficients for different modes depending on fuel technology used were based on TREMOVE project database[1]. The CO_2 emissions are then converted to monetary units by setting a value for each CO_2 ton. The used cost of 20US$ per CO_2 ton was obtained from a long term study of the transport sector undertaken by Burtraw and Parry (2011). In this study other values are tested up to value of 40US$ per ton, being the used value

[1] TREMOVE (2007). A policy assessment model to study the effects of different transport and environment policies on the transport sector for all European countries. Brussels, Belgium, European Commission, Directorate General Environment, Unit C.5 Energy.

their more plausible estimate of the transaction cost that CO_2 emission may achieve in the market around 2040. As in other studies in the sector that try to estimate future impacts of policies and economic scenarios, the values obtained are considered fixed in time due to the consideration of the increase in the unit cost will be equivalent to the depreciation of the costs relative to the base year of analysis.

3. **Number of fatalities.** The estimation of the total number of road traffic fatalities under new economic and mobility scenarios was calibrated using data from the European Union countries in the period 1995-2010. This data incorporates the standard path that countries observed by introducing traffic safety measures in urban and interurban traffic. The model estimated under a logistic function specification shows a good fit in the number of fatalities per million inhabitations linked with the ratio between the vehicle travelled kilometers and the GDP. As expected, the decoupling of economic development with mobility will allow reducing the risk of road fatal incidents ([1]).

$$Fatalities\ per\ million\ inhabitants = \frac{142.85}{1+EXP^{\frac{4.07-5.70\times VKMT\times 200}{GDP}}} \quad [1]$$

The estimation of the monetary value of human life road traffic fatalities was estimated based on a study that collected data on the values of statistical life of insurance companies in several countries around the world (Miller, 2000). The obtained data allowed producing a unit value of road fatalities in function of the GDP per capita ([2]).

$$Yearly\ fatalities\ costs = EXP^{-1.99+LN\,(\frac{GDP}{POP})} \times 1000\ \times Fatalities \quad [2]$$

4. **Modal share (%).** Modal share consists in the distribution of total trips by mode (private transport, public transport and non-motorized transport). This indicator is important to understand how mobility will be exerted in each scenario, being an aggregate indicator of sustainability of the sector.

With this set of indicators, we may be able to quantify externalities that are generated to the society in each scenario and policy package, under the sustainability framework. The comparison of outputs obtained for each intervention plan scenario and the baseline scenario (no policies or business as usual) can provide an estimate of the cost of doing noting or of no intervention, that then can be contrasted with the costs of intervention estimated as a simplified Cost-Benefit study.

IMPLEMENTING THE METHODOLOGY IN A CASE STUDY

The proposed methodology has been applied to three different cities of Kazakhstan (Almaty, Astana and Aktobe) as part of a study conducted for the Asia Development Bank by the

Fundación Empresa Universidad de Zaragoza[2]. Kazakhstan is a country located on Central Asia, northwest of China; a short distance west of the Ural River in eastern-most Europe. The main characteristics of this country - landlocked condition, a vast territory and consequent uneven spatial distribution of population - make Kazakhstan an economy much dependent on transport to ensure relation between social and economic centers and respective agents. According to the government officials the share of transport costs in the final cost of goods is about 8-11%, while in typical industrialized countries this figure is around 4-4.5%. It is also by geographic position a transit country between Europe and Asia. These factors reflect in the urban economics of the country with urban areas located far apart and subject to high costs to receive their supplies (ADB[3], CIA[4]).
A population of around 15 million people, 120 different ethnic groups, is dispersed over the territory, 55% of which live in urban areas. Another characteristic of the country is the concentration of urban settlement areas in the South East, with three cities representing half of the population of the main eleven cities (Almaty, Astana and Aktobe).

Assessment of the current urban mobility situation

Urban transport systems of Kazakhstan cities are composed by buses, trolley-buses, trams, gazelles and taxis. Gazelles are small vans, operated informally. Regarding taxis, there are in both official and informal modes and allow for cheaper prices, a greater flexibility and comfort to move in the busy city center (Table 1).

Table 1: Transport supply of Kazakhstan cities

City	Modes			
	Tram	Trolleybus	Subway	Bus
Almaty	2 lines	9 lines	1 line	119 lines
Astana	-	-	-	55 lines
Aktobe	-	-	-	50 lines

The comparative analysis presented in Figure 2 reveals that Kazakhstan cities (Almaty, Astana and Aktobe) have a very strong modal share in favor of private transport with an almost complete absence of pedestrian mobility. Observing the most developed cities in the world is possible to understand that cities striving for sustainability have a strong investment in public transport and in non-motorized means, the opposite of what is happening in Kazak cities.
Given the evolution of the cities of the world, the natural trend for Kazakhstan cities, in the absence of any corrective action, will be an increase in car ownership in a more than direct proportion to GDP growth. This will mean high congestion, pollution, the near absence of pedestrian mobility (Figure 2) and low quality of life.

[2] Dopazo, C., Ferrão, P., Fueyo, N., Gomez, A., Macário, R., McCarthy, P., Niza, S. and Yang, J. (2012) An Infrastructure Road Map for Kazakhstan - Final Report, Fundación Empresa Universidad de Zaragoza, Asia Development Bank. Available at http://www.adb.org/projects/documents/preparation-sector-road-maps-central-and-west-asia-kazakhstan-tacr.
[3] Asian Development Bank (2012) "Asian Development Bank & Kazakhstan Fact Sheet."
[4] CIA (2012) "World Factbook."

The rise of private transport use with the increase of the average income available per inhabitant is an observed tendency in modern societies. Yet, this trend is emphasized by the lack of good public transport infrastructure and a favorable culture towards the private transport. Kazakhstan cities present a high share of private transport, around 70%, similar to the pattern of American cities (Figure 3). Yet, European cities present a different pattern, especially the ones that strive for sustainability, tend to have a share of private transport around 50%. This indicates a need for a stronger investment in public and non-motorized modes in Kazakhstan cities.

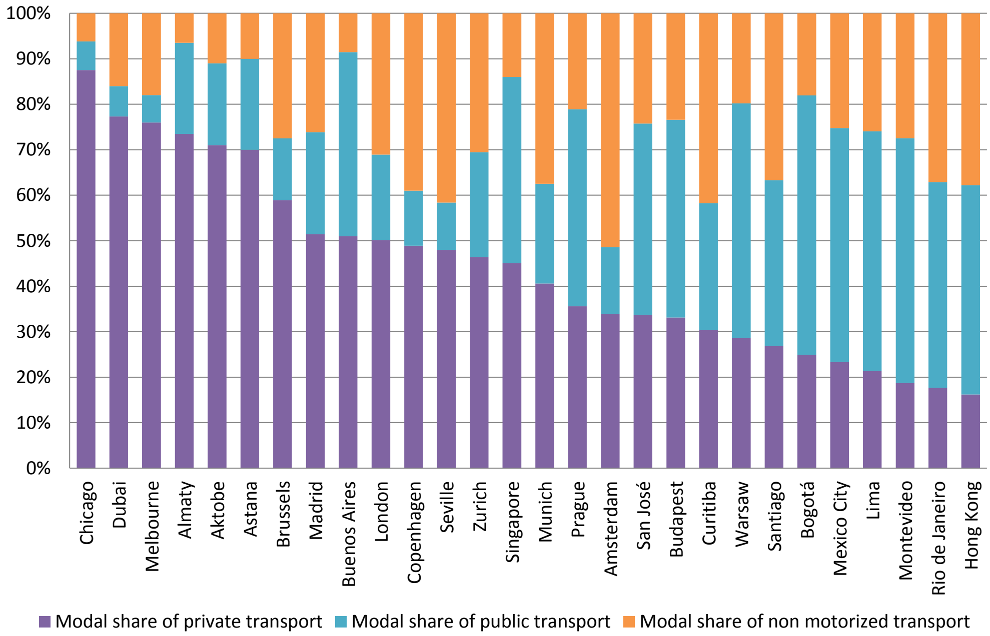

Figure 2: Modal share of several cities Sources: (UITP, 2001; CAF, 2007)

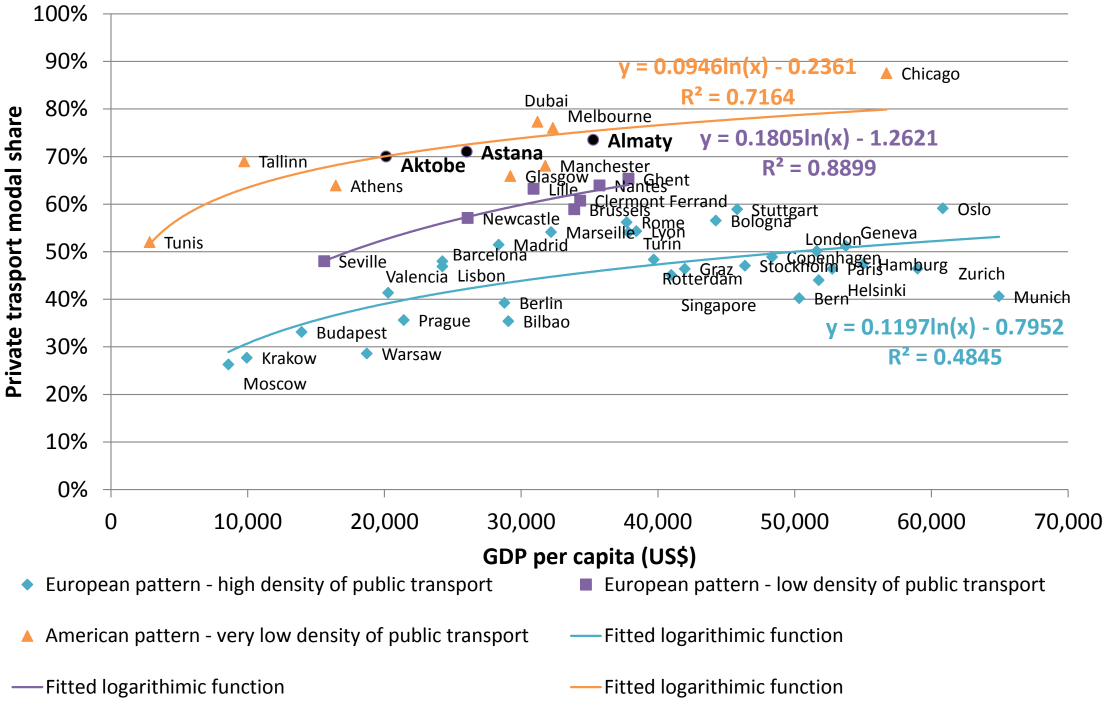

Figure 3: Private transport modal share benchmark of Kazakhstan cities Sources: (UITP, 2001; CAF, 2007)

The observed path of Eastern and Western European countries showed considerable decrease of road fatalities, especially due to a considerable modal share diversion to public transport and non-motorized transport. This change corrected by the GDP showed a considerable decrease especially in Eastern European countries (Figure 4). Almaty is approaching the threshold of 140 fatalities per million inhabitants which is above the observed trend of European countries for the same level of vehicle travelled kilometer per GDP. This fact can be related with the absence of traffic measures to protect pedestrians and the obsolescence of the traffic control infrastructure. Yet, this trend might change if similar safety measures on urban traffic to the European countries are introduced. This has a positive correlation with the use of individual motorized transport.

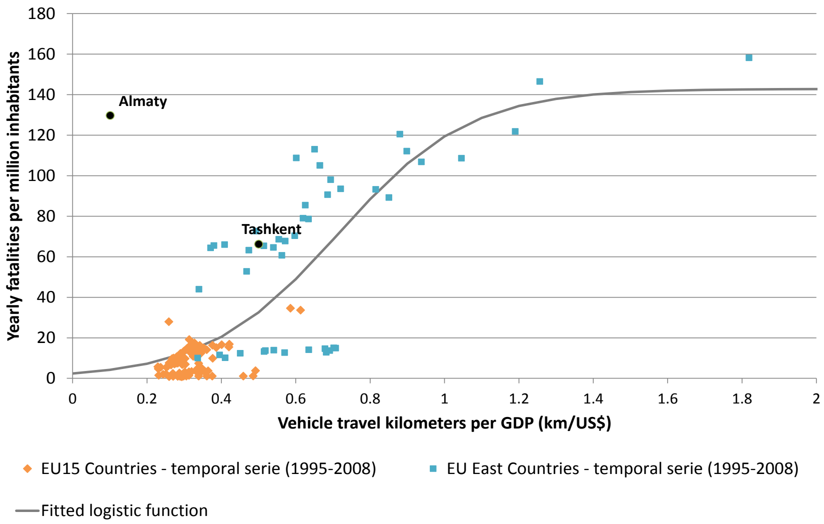

Figure 4: European road safety trend (Source: Eurostat, 1995-2008)

These parameters, used in the calibration of the demand forecasting model were estimated based on urban mobility databases (UITP and CAF) which contain detailed accessibility and mobility data for more than 70 cities around the world. A more detailed description of the demand forecasting model used can found on Martínez et al (2013).
The outputs of this calibrated model for the base year (T0 – 2010) are presented in Table 2. The results show that the historical capital of the city and largest city (Almaty) presents high externalities derived from urban mobility (see Table 2).

Table 2: Estimated mobility externalities in 2010 (T0)

	Congestion costs ($ million/ year)	CO_2 Emissions (tons/year)	Number of fatalities per year
Almaty	**299**	**3,097**	**6**
Astana	**35**	**1,312**	**3**
Aktobe	**3.2**	**303**	**1**

Setting a vision for the urban mobility of the study area

The vision for the Urban Mobility Sector was defined having in consideration the main government strategic guidelines and world trends in the sector especially the ones related with sustainability. Three main goals were established for the urban mobility systems of the country having in consideration the time horizon of 2040:

- Major cities in Kazakhstan should approach by 2040 a modal mix of 50% of private transport, 30% by public means and 20% of pedestrian and cyclist's mobility, similar to many European cities (economic sustainability)
- By 2040 the total amount of CO_2 emissions in Kazakhstan cities should decrease 50% (environmental sustainability).
- Road safety should experience a drastic improvement with a reduction from present values of 130 passenger transport fatalities/million inhabitants to about 30 for the national average by 2040 (social sustainability)

In order to support the defined vision, a set of two scenarios for the future were considered. For each scenario were considered different market shares for public and private motorized transport as well as estimated demand. These scenarios are defined as Moderate Growth and High Growth. Moderate Growth is composed by selecting the expected trend for the variables of GDP and population growths for the year 2040. High Growth is assembled by combining a high degree of GDP growth and a high population growth of the cities for the year 2040. The scenario tree for urban mobility is presented in Figure 5.

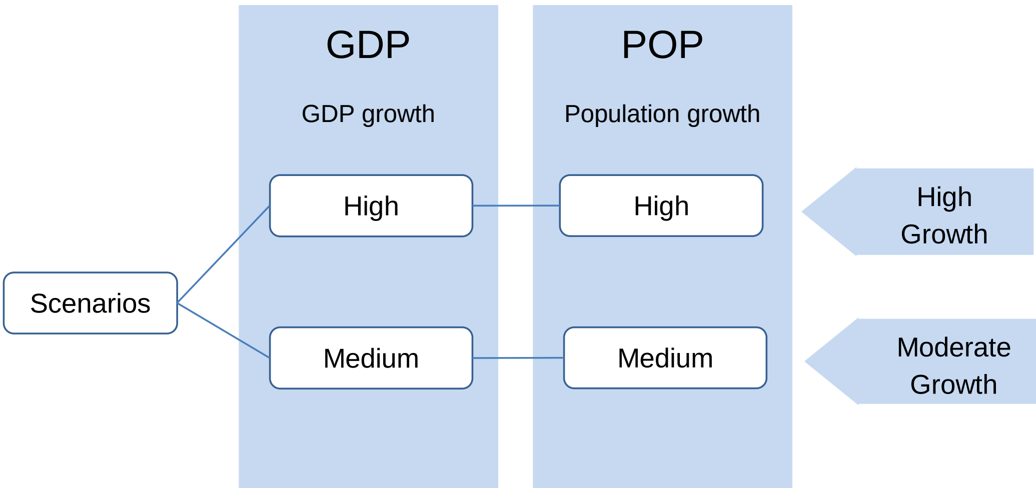

Figure 5: Scenario tree for urban mobility sector

The scenarios were built using two exogenous variables which are the driving forces for the demand growth of urban mobility services. The growth rate of these variables was defined at national level and transposed to the local urban context. These variables are GDP and urban population of the cities. Moreover, the scenarios are built combining possible trends of the two exogenous variables and controlling variables (i.e. urban occupation patterns). Each combination of driving forces was tested with different transport measures. Baseline

scenarios follow the same observed policy trends and vision scenarios encompasses a set of measures aiming to drive a more sustainable configuration for urban mobility.
The scenarios variables affect the values of some model parameters such as the trip generation rate, car ownership rates, etc. These parameters were calibrated using the same benchmark approach as discussed above.

Policy design to achieve the vision

To meet the travel demand, several measures are envisioned for Almaty, Astana and Aktobe over the years. A set of measures are proposed until 2015, 2025 and 2040 in three cities encouraging the use of public transport and non-motorized modes and limiting the use of private transport (Table 3).

Table 3: Type of proposed measures

Encourage public and non-motorized transport	Limiting private transport use	Organize urban logistic
Subway expansion	Parking policy	Infrastructures for loading and unloading
BRT,LRT, IBL, BSS[5]	Urban tolls	-
Intermodal stations	-	-
Tariff integration	-	-

The proposed measures for Almaty until 2015 are the urban mobility surveys, the expansion of subway lines, the implementation of Bus Rapid Transit (BRT) system and Intermittent Bus Lane (IBL) system (Figure 6). These three measures were modeled for the future scenarios. In addition, it is proposed to implement a multimodal interchange station, physical measures for safety and security of non-motorized modes, revise road network hierarchy by widening roadways and implement infrastructures for loading and unloading. The proposed measures to Astana until 2015 (Figure 7) are the implementation of Light Rail Transit (LRT) and BRT systems and the revision of roadways hierarchy by widening roadways with exception of local roadways (hierarchy 4)[6]. In Aktobe, it is proposed the implementation of IBL system (Figure 8). The implementation of an integrated tariff is also proposed until 2015 in three cities.

Measures to implement until 2025

The measures to be taken in Almaty until 2025 are the further expansion of subway (around 50%), the implementation of urban tolls in the city center, parking policy and the implementation of bike-sharing system (BSS). These measures were modeled for the future scenarios (Figure 6). Until 2025, it is recommended the implementation of parking policy in Astana as well as BSS systems. The LRT system will continue until 2025, expanding from city center to the northern part of Astana up to the main railway station, increasing in 10

[5] BRT: Bus Rapid Transit; LRT: Light Rail Transit; IBL: Intermittent Bus Lane; BSS: Bike-sharing system
[6] Hierarchy 1: Arterial road network; Hierarchy 2: Distribution network; Hierarchy 3: Local distribution; Hierarchy 4: Local streets

kilometers length (Figure 7). In Aktobe, it is also proposed parking policy. In all three cities is proposed the further widening of all roadways except local roadways (Figure 8).
To the success of the implementation of the proposed measures it is needed technological resources such as IT for monitoring and control air quality and ITS for flexible management of access to critical areas of the city (CBD).

Measures to implement until 2040

The proposed measures to Almaty until 2040 are the expansion of subway lines (around 30%). In Astana it will be constructed the last section of LRT that will close the loop back to the city center, increasing 18 kilometers length. In Aktobe it is proposed the implementation of BSS system in an area of 93 km^2 which represents a need of 1113 bicycles. In 2040, the private transport modal share will decrease to 37%, 52% and 40% in Almaty (Figure 6), Astana (Figure 7) and Aktobe (Figure 8) respectively, if these measures are taken.

Institutional and regulatory reforms

Allocation of roles and responsibilities as well as price construction mechanisms is rather unclear, revealing a lack of knowledge about real cost structures. There is a lack of transparency in the current mark-up practices used to cover costs. There are no sound structures to ensure stable funds in support of the different dimensions of urban mobility. This situation is perceived by investors and private entrepreneurs as high-risk. No cross cutting procedures are in place to ensure consistency of decisions among interacting sectors, such as land use, energy, environmental and transport. To overcome this situation institutional reform must be implemented and several regulatory pieces are required as well as a consistent approach between them. These measures are to be considered pre-regulatory, that is they must first pave the ground for the accommodation of a successful institutional reform. These are:

- Urban mobility surveys (including passengers and freight) to obtain adequate knowledge on demand flows;
- Implementation of mandatory Master Plans and Plans of Detail;
- Enforce mobility plans in schools and corporations;
- Create Urban Mobility Agencies;
- Enforce quality and environmental certification to all mobility infrastructures and services
- Implement a monitoring system to assess performance of the existing system, benchmark it with international experience. Based on this in-depth result start the design of institutional reform.

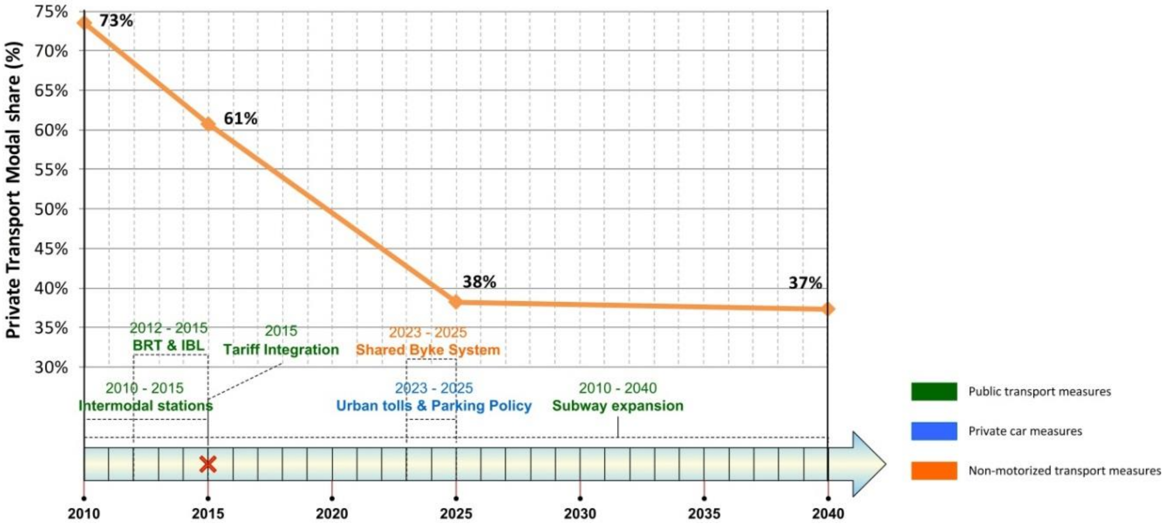

Figure 6: Timeline of proposed measures and its impact on private modal share for Almaty

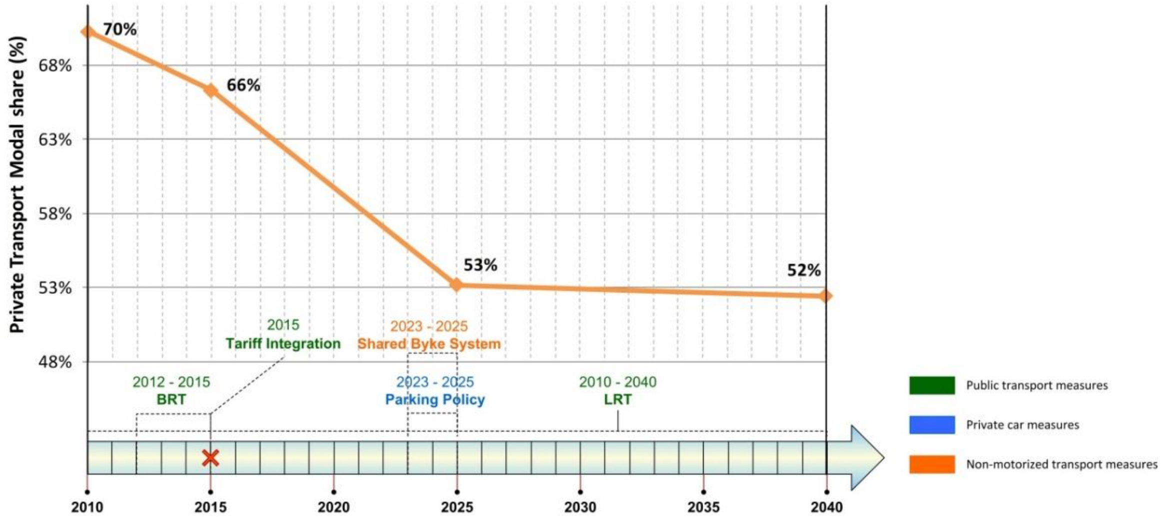

Figure 7: Timeline of proposed measures and its impact on private modal share for Astana

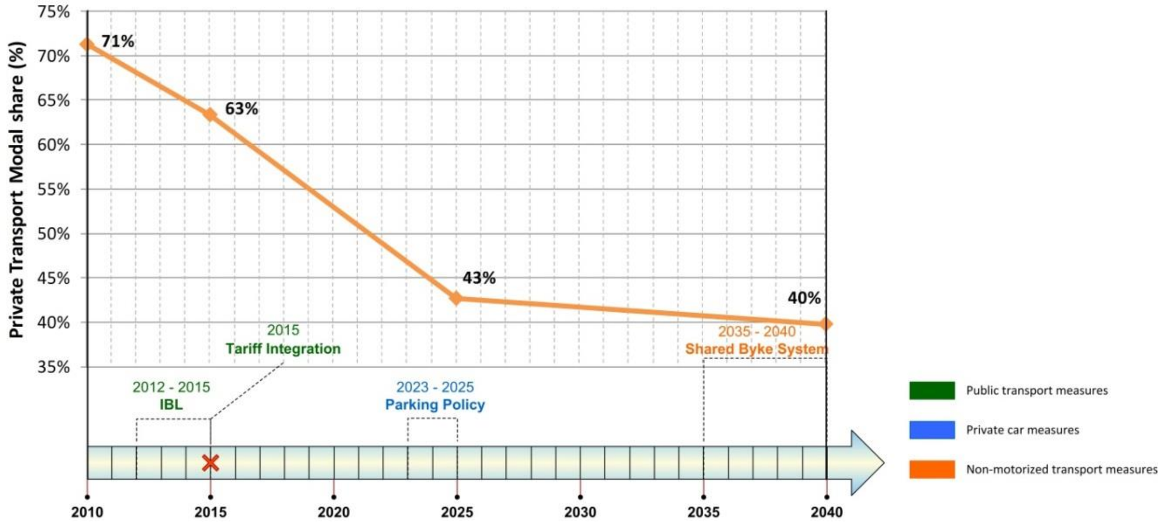

Figure 8: Timeline of proposed measures and its impact on private modal share for Aktobe

Investment and operational costs

Several sources were consulted to estimate the investment and operational costs of the tested measures. Table 4 and Table 5 indicate the unit cost for different modes and measures.

Table 4: Fixed operator cost and operating cost for different modes

Mode	Infrastructure cost	Rolling stock cost	Operating cost		
	Cost per km [MM US$/km]	Cost per km [MM US$/veh]	Operating [US$/veh-km]	Maintenance [US$/day-line]	Operation [US$/pass-km]
BRT	3.00	0.62	1.40	3,579	-
LRT	22.00	3.49	1.80	13,057	-
IBL	0.43	-	5% of infrastructure cost per year		
Subway	78.00	8.75	-		7.42

A unit cost of 3 million US$ per kilometer were considered to estimate the infrastructure cost of BRT as indicated in BRT Planning Guide of ITDP (Wright and Hook, 2007) . Rolling stock and operational costs for Bus Rapid Transit (BRT) and Light Rail Transit (LRT) were based on a study that compares the cost of these different modes (Tirachini et al., 2010). According to the US Government Accountability Office (GAO), the light rail capital costs are about 22 million US$ per kilometer, while buses on arterial streets represent a 98% cost reduction. We considered IBL as a bus on arterial streets which infrastructure costs represents 0.43 million US$ per kilometer (Kubala and Barton, 2003). The yearly operational cost was set at 5% of infrastructure costs. The infrastructure unit cost for subway was based on the example of Berlin project, which cost around 78 million US$ per kilometer (Flyvbjerg et al., 2008). The rolling stock cost and the operation costs were estimated based on the Lisbon subway system (Metropolitano de Lisboa, 2010).

Table 5: Operating, maintenance and capital cost for different measures

Measure	Costs	
Urban tolls	Investment and operating costs [M US$/year]	30.54
Parking policy	Investment[US$/ device]	454
	Maintenance[US$/device]	1826
Major widening (Build-up areas)	Infrastructure cost [US$/km]	0.196
	Maintenance [MM US$/year]	5% of infrastructure cost
BSS	Capital cost [US$/ bicycle]	4,400
	Operation cost [US$/bicycle]	1,700
Tariff integration	Investment cost (software) [US$]	18,200
	Ticket vending machines [US$/unit]	62,344
	Marketing and training [US$]	14,000
	Maintenance cost/ machine[US$/year]	5,250

The investment and operational cost of an urban toll were estimated based on the Stockholm congestion charging system (Eliasson, 2008). The parking investment and maintenance

costs take into account the example of Seattle city [7]. The cost of widening roadways in build-up areas were based in a feasibility study of a concession for the Portuguese Road Management Authority (KPMG, 2008). For BSS we take into account the capital and operation costs per bicycle of Veilib, the Bike-sharing system of Paris (NYC Department City Planning, 2009). The tariff integration costs are calculated based on CIVITAS (2010), an European initiative action that supports cities in the implementation of an integrated sustainable, clean and energy efficient transport policy.
For the investment and operational costs estimation for each new mode (or expansion in the case of subway), the estimation of the number of vehicles for each mode had to be done. The number of wagons of Almaty's subway was estimated take into account the relation between length and wagons of Lisbon subway. The number of buses of BRT of Almaty and Astana were estimated take into account the relation of buses and passenger-kilometers of Bogotá's BRT (Transmillenio) (Hidalgo et al., 2013). The number of vehicles of LRT reproduced the LRT's project of Kazakh Government plan (ADB, 2012). The number of bicycles was estimated take into account the Vélô bike-sharing system (NYC Department City Planning, 2009) (Table 6).

Table 6: Estimated number of vehicles and length by mode

City	Number of vehicles by mode				Modes length (km)			
	Subway	BRT	LRT	Bicycle	Subway	BRT	LRT	IBL
Almaty	60	161	-	407	48	43	-	59
Astana	-	130	49	1556	-	21	47	-
Aktobe	-	-	-	1113	-	-	-	20

Similarly, for the investment and operational costs estimation of the parking policy, the estimation of the number of parking devices had to be done. Hence, it was considered that for each 0.5 hectare there was a parking device which leads to the number of parking devices needed for each city taking into account their entire urban area. To estimate the cost of widening roadways, we take into account the total length of roadways oh hierarchy 1, 2 and 3[8] of Almaty and Astana (Table 7).

Table 7: Number of parking devices and length of widening roadways

City	Number of Parking devices	Length of widening roadways (km)		
		Hierarchy 1	Hierarchy 2	Hierarchy 3
Almaty	67,880	75	204	409
Astana	140,000	176	126	178
Aktobe	46,760	-	-	-

[7] Department of Transportation of the City of Seattle. (2010). "Status and Condition Report (2009-2010): Section 6 Asset Class – Parking Payment Devices." from http://www.seattle.gov/transportation/docs/am/Section%206%20%20%20pay%20parking.pdf.
[8] Hierarchy 1: Arterial network; Hierarchy 2: Distribution network; Hierarchy 3: Local distributor; Hierarchy 4: Local roadways

The total investment for urban mobility network until 2015 for Almaty city is projected to be $888 million. Moreover, the yearly total operational cost of the proposed measures for Almaty is projected at $61 million. The total investment for urban mobility network in Astana until 2015 is lower and is projected to be $461 million. The yearly operational cost of the proposed measures for Astana is projected at $6.8 million. For Aktobe, the total investment for urban mobility network until 2015 is projected to be $7 million and the yearly operational cost of the proposed measures is projected to be $0.65 million. Table 8 presents a summary of these costs until 2040.

Table 8: Investment timeline for the urban mobility sector, $ million. [In square brackets, operational costs, $ million/year]

City		2010-2015	2015-2025	2025-2040	Total
Almaty	Subway expansion	617 [51.84]	601 [50.49]	61.8 [5.19]	1281
	Bus Rapid Transit Corridors	154 [3.55]	-	-	154.9
	Intermittent Bus Lane Corridors	14.5 [0.73]	-	-	14.54
	1 Intermodal station	26.8 [0.77]	-	-	26.86
	Urban Mobility surveys	1.00	-	-	1.00
	Measures security & safety	1.27	-	-	1.27
	Tariff integration	3.3 [0.28]	-	-	3.38
	Widening roads	68.1 [3.41]	19.5 [0.98]	-	87.75
	Urban tolls	-	6.28	-	6.28
	Parking policy	-	6.33 [25.47]	-	6.33
	Bike-Sharing System	-	0.35 [0.13]	-	0.35
Astana	Light Rail Transit Corridor (LRT)	318.3 [3.66]	111 [1.18]	4.7 [0.26]	434.7
	Bus Rapid Transit Corridors (BRT)	98.1 [0.89]	-	-	98.19
	Widening roads	42.4 [2.12]	13.6 [0.68]	-	56.05
	Tariff integration	1.96 [0.16]	-	-	1.96
	Parking policy	-	12.3 [49.51]	-	12.30
	Bike-Sharing System (BSS)	-	1.33 [0.16]	-	1.33
Aktobe	Intermittent Bus Lane Corridors (IBL)	5.17 [0.52]	-	-	5.17
	Tariff integration	1.61 [0.13]	-	-	1.61
	Parking policy	-	4.36 [17.55]	-	4.36
	Bike-Sharing System (BSS)	-	-	0.17 [0.07]	0.17
Total		**1355**	**777**	**66.72**	**2200**

Testing the impacts of the envisaged policies in the mobility scenarios

Using the performance indicators of the system discussed above, they had to be parameterized for each scenario and year of analysis. The parameters for each indicator and city are summarized in Table 9. Other important component of the scenarios for the future is the evolution of the technological composition of the car fleet. The estimated composition of each year interval were based on the forecasting study of the sector (Krail and Schade, 2010).

Table 9: Specifications of the used demand model parameters for each scenario

City	Year	Scenario	VOT (US$/min)	Gas Price	Fare (subway)	Fare (tram/bus/trolley)	Fare (bike)
Almaty	2040	Moderate Growth (Baseline)	$0.105	$0.1023	$0.58	$0.41	-
	2040	Moderate Growth (Vision)	$0.105		$0.58	$0,41	$0.14
	2040	High Growth (Baseline)	$0.136		$0.82	$0.56	-
	2040	High Growth (Vision)	$0.136		$0.82	$0.56	$0.14
Astana	2040	Moderate Growth (Baseline)	$0.090	$0.1023	-	$0.33	-
	2040	Moderate Growth (Vision)	$0.090		-	$0.33	$0.14
	2040	High Growth (Baseline)	$0.120		-	$0.48	-
	2040	High Growth (Vision)	$0.120		-	$0.48	$0.14
Aktobe	2040	Moderate Growth (Baseline)	$0.080	$0.1023	-	$0.27	-
	2040	Moderate Growth (Vision)	$0.080		-	$0.27	$0.14
	2040	High Growth (Baseline)	$0.097		-	$0.37	-
	2040	High Growth (Vision)	$0.097		-	$0.37	$0.14

The results from the backcasting, allow estimating the externalities of the urban transport sector for the tested scenarios. These results are summarized in Table 10, Table 11, Table 12 for the three cities.

Table 10: Yearly congestion costs, tons of CO_2 emissions and number of fatalities for Almaty

Scenario	Congestion Costs (2010 US$/year)	CO_2 Emissions (tons/year)	Number of fatalities per year
Actual	298,718,828	3,097	6
MG_baseline	1,575,939,782	3,126	9
MG_vision	244,662,050	1,762	8
HG_baseline	3,043,804,455	4,138	10
HG_vision	513,898,299	1,858	8

Table 11: Yearly congestion, tons of CO_2 emissions and number of fatalities for Astana

Scenario	Congestion Costs (2010 US$/year)	CO_2 Emissions (tons/year)	Number of fatalities per year
Actual	35,478,750	1,312	3
MG_baseline	260,631,160	2,445	7
MG_vision	172,330,826	1,238	6
HG_baseline	1,760,331,019	4,705	8
HG_vision	860,289,653	2,292	7

Table 12: Yearly congestion, tons of CO_2 emissions and number of fatalities for Aktobe

Scenario	Congestion Costs (2010 US$/year)	CO_2 Emissions (tons/year)	Number of fatalities per year
Actual	3,201,319	303.53	1
MG_baseline	46,589,826	547.79	3
MG_vision	12,252,951	272.19	2
HG_baseline	138,547,024	770.93	3
HG_vision	25,311,641	307.13	2

Table 13 does also present and evolution of three main indicators for the different scenarios from 2010 to 2040, showing the outputs of the envisaged measures and policies in the urban mobility performance.
The amount of CO2 emissions released by motorized transport modes show a significant decreased derived from the introduction of several operational measures such as urban tolls, mass transit corridors (BRT, LRT, etc) and infrastructures for non-motorized mobility. It ensures an integrated approach to enhance environmental efficient solutions (i.e. zero emission vehicles, promotion of pedestrian's routes, etc).
Regarding road safety, it should experience a drastic improvement with a reduction from present values of 130 passenger transport fatalities/million inhabitants for Almaty to about 30 for the national average by 2040. Taking into account the examples of other cities, if some physical measures, norms and legislation are taken, it is possible to reduce the number of passenger transport fatalities.

Table 13: Yearly congestion costs, tons of CO_2 emissions and number of fatalities for Almaty, Astana and Aktobe

<table>
<tr><th>Indicator</th><th>City</th><th>2010</th><th>2040</th><th>% change</th></tr>
<tr><td rowspan="3">Congestion costs ($ million/ year)</td><td>Almaty</td><td>299</td><td>245 | 514</td><td>-18% | 72%</td></tr>
<tr><td>Astana</td><td>35</td><td>172 | 860</td><td>386% | 25%</td></tr>
<tr><td>Aktobe</td><td>3.2</td><td>12 | 25</td><td>283% | 691%</td></tr>
<tr><td rowspan="3">CO_2 Emissions (tons/year)</td><td>Almaty</td><td>3097</td><td>1762 | 1858</td><td>-43% | -40%</td></tr>
<tr><td>Astana</td><td>1312</td><td>1238 | 2292</td><td>-6% | 75%</td></tr>
<tr><td>Aktobe</td><td>303</td><td>272 | 307</td><td>-10% | 1%</td></tr>
<tr><td rowspan="3">Number of fatalities per year</td><td>Almaty</td><td>6</td><td>8 | 8</td><td>33% | 33%</td></tr>
<tr><td>Astana</td><td>3</td><td>6 | 7</td><td>100% | 133%</td></tr>
<tr><td>Aktobe</td><td>1</td><td>2 | 2</td><td>100% | 100%</td></tr>
</table>

Moderate Growth | High Growth

Costs of no intervention

The proposed measures for urban mobility in Almaty, Astana and Aktobe encourages the use of public transport and non-motorized modes which results in private transport modal share diversion. The avoided costs of externalities such as congestion, CO_2 emissions and fatalities are about \$16 billion, \$1.18 billion and \$0.48 billion, respectively, in the Moderate Growth scenario (Figure 9).

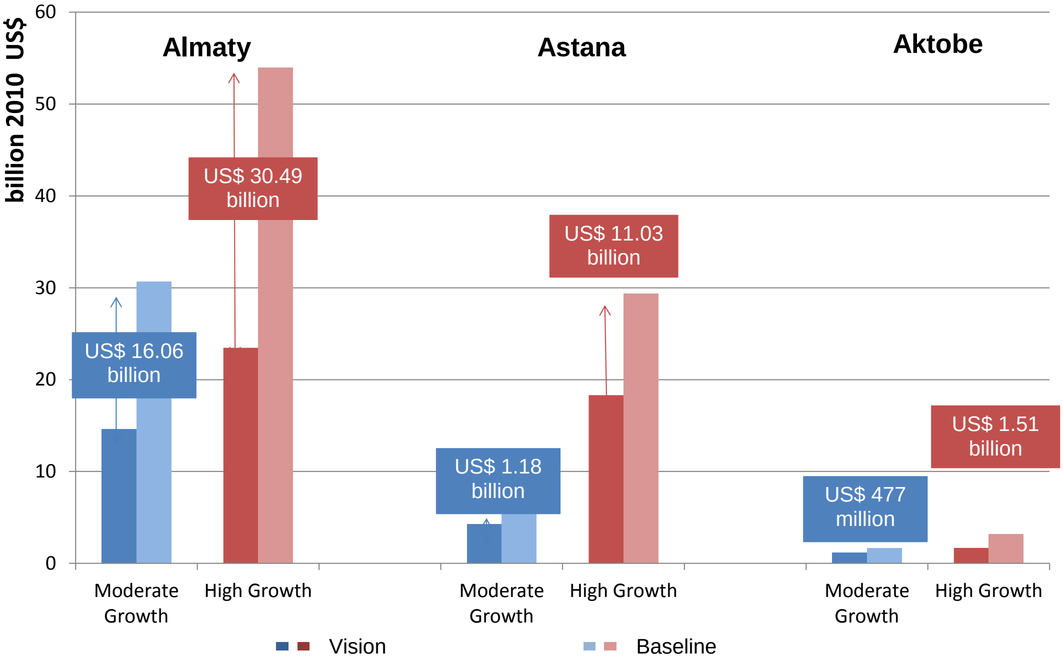

Figure 9: Additional cost of congestion, CO_2 emissions and fatalities (cumulative 2010-2040)

Develop a mobility roadmap

After the development of the backcasting for each city, we can know present a general urban mobility roadmap with the time interval when it should applied in order to achieve the set vision. The resulting roadmap is presented in the next table, specifying the expected impact over the main sustainability pillars: environmental, economic and social.

Table 14: Roadmap summary of the case studies

		T+0 a T+5	T+5 a T+15	T+15 a T+30
Non-physical infrastructure	Governance	UM1: Implement Urban Mobility Agencies	UM19:Sustainable mobility for schools and corporations	UM34:Define contingency plan (emergence response capability) for UM services
		UM2: Revise the technical and regulatory framework and develop Master Plans for UM		
		UM3:Zero Fatalities program for safety	UM20:Integrated land-use, energy and transport master plan for UM	
		UM4:UM surveys (passengers and freight)		

		T+0 a T+5		T+5 a T+15		T+15 a T+30	
		UM5:Schemes for withdrawal of very old cars	[green]	UM21:Quality and environmental certification of all UM infrastructures	[green]		
		UM6:Regulate loading and unloading operation	[blue]				
	Competition	UM7: Financial and quality audits to current UM operators	[orange] [blue]			UM35:Competition in UM services	[blue]
Physical infrastructure	**Asset management, supply**	UM8:Implement BRT systems in main cities	[green] [orange] [blue]	UM22:Introduce a mobility plan for soft modes (walking and cycling)	[green]	UM36:Implement LRT systems in cities of high demand growth	[green] [orange] [blue]
		UM9:Infrastructure for urban logistics (loading/unloading)	[blue]	UM23:Multimodal interchange stations	[blue]		
	Asset management, demand	UM10:Priority UM network for PT; mass corridors and modal insertion (BRT and LRT)	[orange] [blue]	UM24:Parking policy and access to city areas	[green] [orange]	UM37:Congestion management measures (Urban tolls)	[green]
		UM11:Multimodal Interfaces stations (Park & ride facilities)	[orange] [blue]				
	Quality of infrastructure	UM12:Revise road network hierarchy	[blue]	UM25:Recover the walking and cycling infrastructure	[green]		
		UM13:Physical safety and security measures to reduce fatalities	[blue]	UM26:Bike-sharing systems	[green]		
				UM27:Zero fatalities program for safety and security	[blue]		
		UM14:Expansion of subway lines	[green] [orange] [blue]	UM28:Define hierarchical modal structure for mobility systems	[orange] [blue]		
Resources	**Technological**	UM15:Adopt IT systems to manage UM	[blue]	UM29:Reform fleets in line with Mobility Master Plans	[green]	UM38:ITS systems for flexible management of access to critical areas of the city (CBD)	[green]
		UM16:Introduce automatic payment in PT	[blue]	UM30:Adopt information systems to monitor congestion, quality of air and flexible access to CBD	[green] [blue]	UM39:Assess potential for adoption of renewable energy	[green]
				UM31:IT devices in UM for automatic collection of information	[blue]		
	Human	UM17:Training and education for UM	[blue]				
	Funding	UM18:Funding and Financing scheme for modernization of infrastructures	[blue]	UM32:Introduce accessibility value capture for UM	[blue]	UM40:Mandatory mobility funds for all large investments in real estate	[blue]
				UM33:Introduce earmarking of value captured fund for UM	[blue]		

[green] Environmental performance [orange] Social equity [blue] Economic efficiency

The envisaged plan represents an investment of 2,200 million dollars in the three cities spanned of the next 30 years (Almaty – 1.583 million dollars, Astana – 604 million dollars and Aktobe – 11.31 million dollars).

CONCLUSIONS

Our analysis has shown that Kazakh cities currently present a rate of fatalities much above the observed trend in Europe. Both Eastern and Western European countries show a considerable decrease in road fatalities, mostly due to a substantial transfer of the modal share towards public and non-motorized transport, together with strong investments in traffic calming, regulation, enforcement and education. This is a pattern that Kazakhstan can copy.
To avoid the high costs of congestion in the future, it is crucial to place a strong emphasis in public transport and soft modes (walking and cycling) in the main cities, together with the restriction of private transport. These policies not only avoid congestion, but they also promote more sustainable cities with lower pollutant emissions.
To overcome the lack of transparency perceived by foreign investors, institutional reform must be implemented and several regulatory pieces are required. Measures like urban mobility surveys, the implementation of mandatory Master Plans, the creation of Urban Mobility agencies, and the development of a monitoring system to assess performance of current systems are a pre-regulatory requirement to pave the way for a successful institutional reform.

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