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Research Article

A Risk-based Assessment of Road Networks: Country Case-study and a Wide Range of Applications Covering from Logistics Operations and Security Controls to Regional Geo-economic Development

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Abstract

In this paper a series of strategic logistics concepts, like transportation axes "attractivity", substitution costs, geo-economic and emergency traffic paths, nodes and gates, are introduced and evaluated in a country case study assessing regional road networks. Based on the above mentioned, risk analyses are performed with regard to the logistics emergencies. Turkey's main road network is being accordingly examined along with the policy implications of the results provided by current political changes in this country. This study exhibits that the R.T. Erdogan's, AKP party-ruled, governments, caused not only high-level geopolitics and geo-economics repercussions but also have severe economic and logistics effects, activating incentives and infrastructure investments, especially in the so called Anatolian areas. The analysis of Turkey's internal geo-economic trends offers notable insight into the mechanism controlling in general the regional socio-economic attractiveness and efficiency. In this context the socio-economic indicator: "Roads Network Development" on regional basis and for each year of the period 1995-2012, has then been chosen and analyzed statistically as dependent variable in relation to the election results and the consequent political changes between the so called Kemalist and political Islam regimes; the results surprisingly confirm the relevant hypotheses tested.

Keywords: *Geographic Information System, Road Networks*

1. Introduction

A previous study had discussed a model for assessing how the internal politics dynamics in a country may influence both its economy and society. It is a pre-requisite though that such political revisions should involve large-scale governmental reforms, creating deep ideological rifts between the former and the latter regimes. They launch geo-cultural and geostrategic reorientations, but also transform the daily life of the citizens in terms of prosperity, safety, security and quality of life. The case study of Turkey's political transformation over the last approximately twenty years, ignited by the Islamic or the so called neo-ottoman political parties prevailing over the long lasting Kemalist tradition, offers an ideal environment for testing hypotheses of politics and society interactions, based on the factual findings about the consequences of the institutional re-arrangements establishing the new Islamic political order (Karkazis, Baltos, & Balodis, 2018).

In the context of the first part of this analysis, titled Model "A", we first map out a certain 20-year period of parliamentary election results, covering a decade before and after the crucial 2002 time-point, when the change from the Kemalist to the Islamic political governments took officially place. The changes are reflected in a first set of maps (Figure 1). The socio-economic indicator:

"Road Network Development" on regional basis and for each year of the period 1995-2012, has then been chosen and analyzed statistically, therefore, as dependent variable in relation to the election results and the consequent political changes between the so called Kemalist and political Islam regimes (Baltos, Vidakis, & Balodis, 2017).

2. The Importance of Regional Road Networks Research and Quantitative Analysis

Turkey's roads network exhibits a rapid but highly imbalanced growth during the whole 20th century under the ideological and sociopolitical prevalence of kemalism. Imbalances were due to two main factors:

- Certain transport development policies which were giving emphasis and high priority to the establishment of an efficient road network connecting the industrial centers of the triangle Istanbul-Izmir-Ankara and
- Turkey's geomorphology and especially the mountainous barriers in Black Sea, Mediterranean and Eastern Regions, which impose extreme difficulties in the deployment of efficient road sub-networks connecting Central Region (a region of high strategic importance) with the above three regions.

As a consequence of the above factors Turkey's road network exhibits high risks related to emergency cases. These risks, perceived as probabilities of limited effectiveness, are also briefly assessed in this paper. The strategic transport analysis concepts employed in this part (transport axis attractivity, substitution cost and geo-economic traffic) were further introduced in detail by J. Karkazis (Karkazis, 2007). They were originally applied for the strategic analysis of Turkey's main road network through the geographic information system (GIS) "Ptolemeos IV – Transport Analysis –Turkey" (Karkazis, 2012). They were also applied for the optimal location of supply centers on Turkey's main road network (Karkazis, 1989). The notions of emergency traffic paths, nodes and gates are additionally introduced along with the main findings of an emergency traffic analysis of Turkey's main road network presented. In the second part of this paper, titled Model "B", a multi-criteria-based risk analysis is performed regarding the emergency traffic nodes of Turkey's main road network.

3. Methodology and GIS applications

3.1 Model A: before and after AKP governments

The hypothesis tested at the first part of the analysis is the following: "*Under the AKP Islamic government the length of the road network was increased at the regions supporting at large the respective regime".* The first set of maps described above (Figure 1), representing the dependent variable of the fundamental political changes, is "interleaved" with another set of respective maps (Figures 2 and 3) corresponding to a dependent variable, i.e. elections per region/per year and development of the road network over the same space-time reference points. The overlapping of the data carrying layers is projected over a number of years and is eventually identified in a specific region, where an alternate map shows the sequence of the Kemalist-Neo-Ottoman governments as well as the fluctuations of the data of the dependent variable for the same period of time. In order to evaluate political-social relations through Cartography and Geographic Information Systems, the following technical parameters were applied:

Geographical display of statistical data • Source of statistics: OECD (OECD) • Country: Turkey - Territorial Unit: Regions [EUROSTAT NUT2] • Software: ArcGis 9.3.1 - Date: WGS 1984 • Measurement indicators: Elections (1995-2011) + Economic factor (e.g. length of road network, 1995-2012).

This exercise respected methodological integrity, statistical reliability and modeling significance, however, it is limited to a key but specific reference period. Islamic governments have continued until nowadays and variable contingencies have evolved their behavior and changing trends. The same model, then, may be extended beyond 2012, in order to demonstrate the impact on society caused by the transition from early to late phases of neo-Ottomanism. Additionally, the population of the variables to be examined can be enriched, since the mapping of statistical data through the Geographic Information System can continue for other variables beyond the one presented in this study.

3.2 Sensitivity axes and risk analysis

A multi-criteria analysis based on the notion of ranking efficiency is performed in order to assess the risk associated with the axes characterized by high emergency traffic. The criteria employed are the emergency traffic (attractivity) of a transport axis, the respective average substitution cost and the number of high substitution cost optimal paths passing through an axis which refers to the part of the emergency traffic corresponding to substitution cost exceeding a distance of 100 km. Note at this point that an axis is characterized by ranking efficiency at level n if the values of the above three criteria for this axis are among the n highest for each one of the criteria. By employing sequentially (with n=1,2,3, …) the technique of ranking efficiency we can sort in decreasing order of efficiency the axes processed. The multi-criteria analysis was based on a ranking efficiency at level 80, corresponding to the best quarter of the total number of axes of the system.

4. The Mapping of the Election Results

Another clear limitation of this study is the degree of representation of less populated social groups, since the parties which were included measured by the percentages of votes in electoral periods, scoring more than 10%, otherwise they by law excluded of Parliament. In addition, the pro-Islamic and pro-Kurdish parties have been repeatedly prosecuted, disbanded and re-assembled several times. Nationalist parties, then, consistently and repeatedly have voters and political ideas at both the Kemalist and the Islamic sides, therefore, they have been excluded from the assessment as third-parties and non-governmental forces (Hazama, 2007).

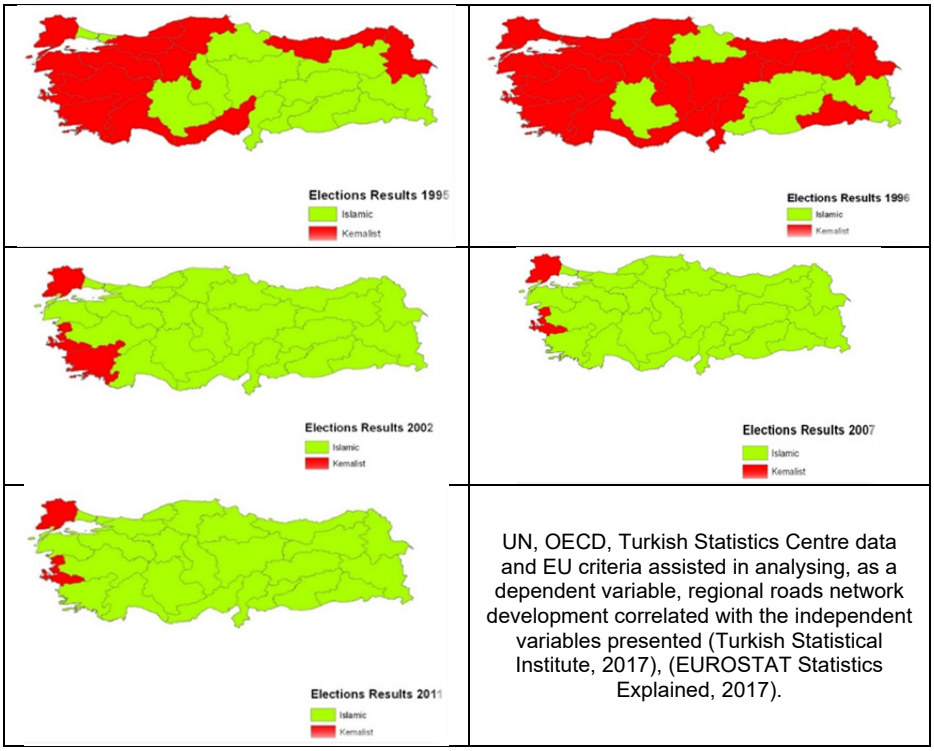

Figure 1: Model A – 1st set of maps: Parliamentary results 1995, 1996, 2002, 2007 and 2011. Regional Elections results presented on the NUTS 2 territorial unit basis. Red (or dark grey for b/w images) and green (or light grey) colors reflect kemalist and pro-Islamic majority votes respectively (Karkazis, Baltos & Balodis, 2018).

Although there is no easy solution to the problem of inadequacy of socio-economic data at regional / provincial level, recent progress in the publication of economic data by the State Institute of Statistics of Turkey in view of accession negotiations with the European Union at provincial/regional level, combined with the corresponding OECD data, has made it possible to test relevant assumptions. Mean, standard deviation (SD) and median, as well as interquartile ranges were used to describe the quantitative variables. For the comparison of quantitative variables between two groups, the non-parametric Mann-Whitney criterion was used. The years recorded, the political status (Kemalist / Islamic) and the interaction between them were used as independent variables. Significance levels are two-fold and the statistical significance was set to 0.05. The SPSS 19.0 and STATA 9.0 statistical programs assisted in the data analysis.

4.1 Election results per region & development of Road Network

Given the measurements for the length of the regional road network in twenty-six regions, the following tables were prepared presenting the data statistically processed for the years 1995 to 2012. The length of the road network ranged from 529.1 km (SD = 83.7 km) recorded in the TR10 area to 4101.8 km (SD = 100.6 km), recorded in the TR72 region. Other tables also prepared for the description of the length of the road network by region as shown in the years 1995 to 2012 depending on the political status (Kemalist / Islamic): The graph below visually demonstrates the length of the road network of the different regions separately for each year of recording, based on additional tables with the descriptive statistical measures for the length of the road network over 18 years separately for "Islamic" and "Kemalist" governments.

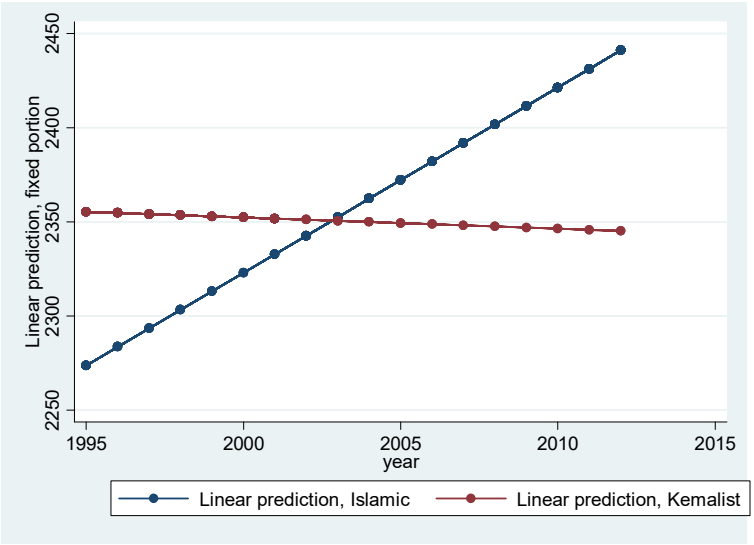

Figure 2: Overall, there has been a significant increase over the 18 years (1995 to 2011) in the road network, but this is only evident in the Islamic government areas (Karkazis & Baltos, 2018).

Hypothesis confirmation: Overall, there has been a significant increase over the 18 years (1995 to 2011) in the road network, but this is only evident in the Islamic government areas, as shown in the following graph and the statistically significant interaction between the election result and time ($p < 0.001$). So it seems that the areas where the election was "the Kemalist government" have stalled in the development of roads, while there has been significant growth in the areas where the election was "Islamic government".

4.2 Mapping of socio-economic changes due to political changes with Geographical Information System

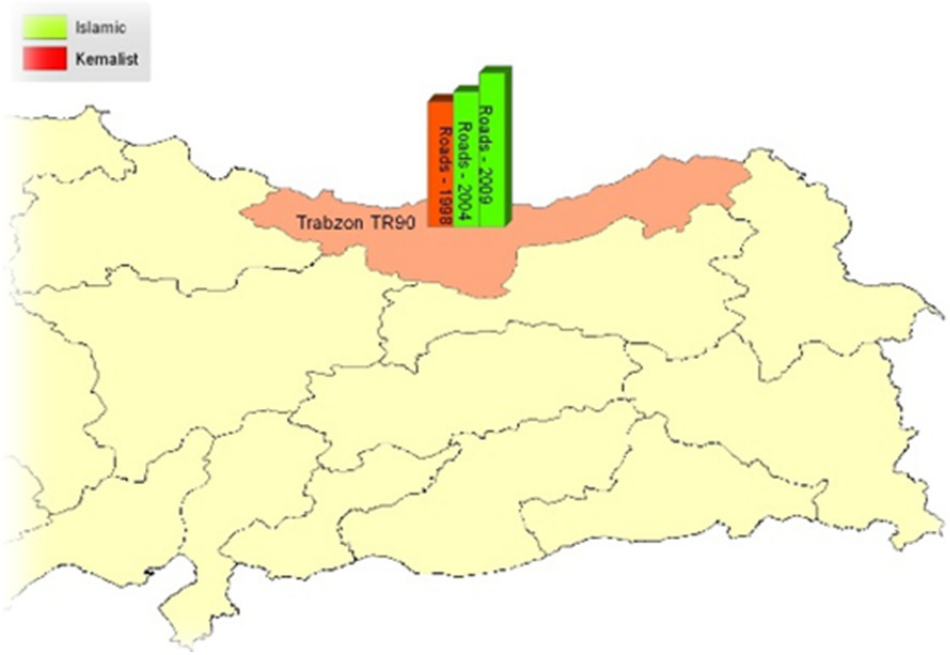

Figure 3: The dynamics of regional road network in Trebizond (NUTS 2: TR 90) region over the years before and after AKP takes power. Kemalist status in red (or dark grey for b/w images)-colored and post-kemalist in green (or light grey)-colored bars.

5. Model B – GIS and Sensitivity Traffic Analysis before AKP governments

This case study is based on the Kemalist era, although it can be further projected in the neo-ottoman period. Its added value emanates from the comparison between its results and those already discussed at the previous Model A analysis. Additionally, Model B utilizes the gravity centers mapping, depicts thoroughly the shifts of the logistics centers, while it facilitates operational research, crisis management and risk assessment evaluations toward military, business and civil situational awareness and mitigation of damages, threats and disaster recovery.
The key index in this analysis is the Transportation Axis Attractivity (TAA). The notion of the TAA represents the un-weighted traffic passing through a given axis in contrast with the regular weighted traffic represented by the geo-economic (social or economic) traffic (Montemanni & Gambardella, 2004). Note that in the latter case the term ‘weight’ represents the population or GDP of the provinces which correspond to the capitals determining the end nodes of the optimal paths passing through the given axis. In this sense TAA can be used as a representative index of the Sensitivity Traffic passing through a given axis. The term ‘emergency’ as a sensitivity indicator may cover entrepreneurial, civil and military logistics issues. Thereon, ‘emergency traffic’ will be employed as an equivalent of the term ‘attractivity’.

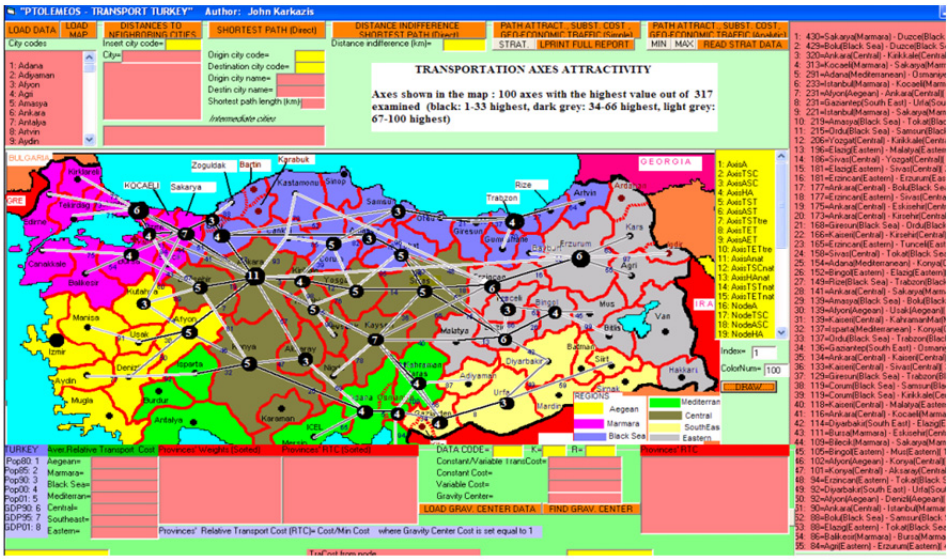

Figure 4: Transportation Axes Attractivity

Figure 4 shows Turkey's 100 transportation axes (out of a total of 317 processed by Ptolemeos GIS) analyzed with the highest emergency traffic which are further distinguished in three sub-categories:

1. Axes characterized by extremely high (e.h.) emergency traffic (indicated with black color: axes 1-33 in the sorted list at the right of the map)
2. Axes characterized by very high (v.h.) emergency traffic (indicated with dark grey color: axes 34-66 in the sorted list at the right of the map)
3. Axes characterized by high emergency traffic (indicated with light grey color: axes 67- 100 in the sorted list of the 100 axes)

5.1 Extremely high emergency traffic paths

A path is defined as a series on sequentially connected axes (Erlander & Stewart, 1990).

There exist 2 paths of national importance characterized by e.h. traffic that is consisting solely of e.h. emergency traffic axes:

a. The path connecting Istanbul (and the socio-economic and industrial gravity centers of Western Turkey) with Erzerum (the main urban and economic center of the Eastern Region) as well as with Erzincan and Bingol, two other centers of this region: Istanbul-Sakarya-Ankara-Kirikkale-Yozgat-Sivas-Erzerum
b. An alternative path connecting Istanbul with Erzerum and the other centers of the Eastern region lying north of the previous one and passing through the southern part of Black Sea Region: Istanbul-Kocaeli-Duzce-Bolu-Amasya-Tokat-Sivas-Erzurum

Both the above paths pass through Sivas a transport gravity center of special importance to which 4 e.h. emergency traffic axes are converging.

There exist also 2 paths of regional importance one in the southern part of the country and the other in the Mediterranean Region:

a. The Konya-Adana-Osmaniye path connecting the western part of the country (Izmir, Istanbul and Ankara socio-economic and industrial centers) with the socio-economic and industrial centers of the South (Black Sea and the Southeast Regions).
b. The Samsun-Ordu-Trabzon-Rize path connecting the northern coastline parts of Black Sea Region from Samsun to Rize and the borders with Georgia.

5.2 High emergency traffic nodes

The transport nodes (capitals) of the country to which four or more axes of high emergency traffic converge are thereon characterized as Sensitivity Transportation Gravity Centers (ETGC) (Xu, Liu, Huang, Zhang, & Luan, 2007). There exist 32 such ETGCs distinguished in categories. The regional distribution of the above ETGC is as follows:

Central Region: 10 - Black Sea Region: 7 - Eastern Region: 5 - Marmara Region: 4 - Mediterranean: 3 - Aegean Region: 2 - Southeast Region: 2

It is evident from the above that a very large proportion of Turkey's emergency traffic passes through Central Region and in particular Ankara.

5.3 Sensitivity traffic gates

Four among the above ETGCs (lying peripherally round Ankara) have a special significance as 'gates' of emergency traffic from the big geo-economic gravity centers of the western part of the country (in Marmara, Central and the Aegean Regions) to Black Sea, Mediterranean, Eastern and Southeast Regions:

1. Bolu: Western gate of emergency traffic from Marmara to Black Sea and Eastern Regions and northern gate of emergency traffic from Central Region to the western part of Black Sea Region.
2. Corum: Eastern gate of emergency traffic from Marmara and Central Regions to the central and eastern part of Black Sea Region.
3. Sivas: Western gate of emergency traffic from Central and Marmara Regions to the Eastern Region.
4. Kayseri: Western gate of emergency traffic from Central and Marmara Regions to the Southeast Region and the northern part of Mediterranean Region.
5. Aksaray: Northern gate of emergency traffic from Central and Aegean Regions to the Black Sea Region.
6. Konya: Northern gate of emergency traffic from Marmara Region to the Black Sea Region.

The above six ETGCs represent "bottleneck" nodes for an effectiveness-oriented analysis of the emergency traffic of the country. Among them Kayseri and Sivas (with 11 and 7 high emergency traffic axes converging to them respectively) represent the principal transportation gravity centers acting as gates of emergency traffic from the western to the eastern part of the country. The ranking of the emergency traffic axes according to the above criteria is presented on Figure 4. The most risk-exposed areas then were:

A. The northeastern part of Black Sea Region (with 4 out of 11 axes) and specifically the extremely high-risk emergency path Samsun-Ordu-Trabzon-Rize-Artvin leading to the borders with Georgia
B. The southern part of Mediterranean Region (with 2 axes) and specifically the extremely high-risk emergency path Icel-Adana-Osmaniye leading to the borders with Syria.
C. The northern part of the Eastern Region (with 2 axes) and specifically the extremely high-risk emergency path Bayburt-Erzurum-Kars leading to the borders with Armenia.
D. The western part of the Southeast Region (with 1 axis) and specifically the extremely high-risk emergency axis Urfa-Gaziantep leading to the borders with Syria.
E. The Aegean Region with 2 extremely high-risk axes: Aydin-Denizli and Afyon-Usak.

6. Security Risk Analysis, Conclusions and Policy Implications

A multi-criteria analysis based on the notion of ranking efficiency and employing 3 criteria was performed in order to assess the risk associated with the nodes characterized by high emergency traffic. The criteria employed were:

1. The emergency traffic (attractivity) of a node (nET)
2. The average substitution cost of a node (nASC)
3. The number of high substitution cost optimal paths passing through a node which refers to

the part of the emergency traffic corresponding to substitution cost exceeding 100 km (nHET)

The multi-criteria analysis was based on a ranking efficiency at level 24 corresponding to the best 30% of the total number of nodes of the system. The most risk-exposed regions were again the Black Sea Region with 2 extremely high-risk emergency traffic nodes (Trabzon and Ordu) and the Mediterranean Region also with 2 extremely high-risk emergency traffic nodes (Adana and Osmaniye).

The hypothesis tested at the first part of the analysis is that under the Islamic government the length of road network was increased at the regions supporting at large the respective regime. The observations were quantified, while the whole exercise has been executed without reference to the ethical or political judgement on the governmental priorities. The hypothesis has been indeed statistically and GIS-tested, given that there has been a significant increase over the 18 years (1995 to 2011) in the road network, but this is only evident in the Islamic government areas, as it was hypothesized; the areas where the election was "the Kemalist government" have stalled in the development of roads, while there has been significant growth in the areas where the election was "Islamic government".

This case study (Model B) is based on the Kemalist era data, although it can be further projected in the neo-ottoman period. Its added value stemmed out from its combination with the results discussed at the previous Model A analysis. The latter “bridges” the Kemalist past with the Neo-Ottoman present, in the way Samuel Huntington (Huntington, 2007) metaphorically explained that a bridge is an artificial means between two inevitably disconnected lands, whereas Model B utilizes the gravity centers mapping, the logistics strategic improvements needed as well as the crisis management and risk evaluations possibly toward military, business and civil control management, mitigation of threats and disaster recovery.

7. Conclusions and Policy Recommendations

The two-fold analysis presented above introduced a series of strategic logistics concepts, like transportation axes “attractivity”, substitution costs, geo-economic and emergency traffic paths, nodes and gates as well as country case study assessing regional road networks. Risk analyses were performed with regard to probable logistics emergencies. Turkey’s main road network was being accordingly examined along with the policy implications of the results provided by current political changes in this country. The study results in highly recommended public and private sector policies inclusive of logistics planning that takes into account the actual along with the expected/optimized map of the transport nodes (capitals) of any country under examination. Such a planning also outlines the axes of high emergency traffic converge, which were before characterized as Sensitivity Transportation Gravity Centers (ETGC).

Another main feature which is advisable to be examined by any government planning and logistics programming is the identification of highly imbalanced growth during long periods, especially since it is affected by ideological and sociopolitical prevalence of specific political parties and regimes. In the case study of Turkey, the imbalances in discussion were due to certain transport development policies which were giving emphasis and high priority on the establishment of an efficient road network connecting the industrial centers, as well as due to the landscape of Turkey, which imposes burdens in the deployment of efficient road sub-networks. However, the imbalances may be mitigated through the increase of infrastructure capacities, at least in service of regions with high strategic importance. The last but not least lesson learned, possible to be generalized for application in other countries, is the prevention of high risks related to emergency incidents. These risks, perceived as probabilities of limited effectiveness, should be critical factors for decision making. The strategic transport analysis concepts employed before are a “sine qua non” pre-requisite of effective and efficient national and regional governance.

As it is demonstrated on the basis of indicative factors analyzed, the sustaining growth of Turkey proved lately possible only by being supported by brave transport capacity building and construction projects implementation. As we may retrospectively witness, it is remarkable that the Turkish economy managed to run through recent and rough worldwide crises with minor losses. Its

survival against the current economic decline, fueled though by adversary political circumstances, is another evidence of how the growth scenarios chosen by the Turkish leadership over the last decades triggered decisive logistics planning and long-lasting progress, delivering improvements in terms of resilience, entrepreneurship and macro-economic sustainability.

The results of the research applied exhibited that the latest R.T. Erdogan's, AKP party-ruled, governments, caused not only high-level geopolitics and geo-economics repercussions but also severe economic and logistics effects, activating incentives and infrastructure investments, especially in the so called Anatolian areas. The analysis of Turkey's internal geo-economic trends offers notable insight into the mechanism controlling in general the regional economic attractiveness and efficiency. In this context the socio-economic indicator: "Roads Network Development" on regional basis and for each year of the period 1995-2012, could be considered one of the numerable indicators that should follow up in the same context of analytical modeling. In other words, indicators recalled from OECD and UN relevant sets of indices could further enrich this research and its policy implications. With regard to the chosen and analyzed statistically as dependent variable ("roads network") in relation to the election results and the consequent political changes between the so called Kemalist and political Islam regimes, the results remarkably confirmed the respective hypotheses tested.

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