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**Authors:**

Franz FÜRST, Jad ISAAC, Isam ISHAQ, Jay KAPLAN, Hanna MAOH, Ingo PETZOLD, Lutz PLÜMER, Ilan SALOMON, Carsten SCHÜRMANN, Klaus SPIEKERMANN, Michael WEGENER

**Title:**

**Sustainable Transport Planning for Israel and Palestine**

**Abstract:**

The paper presents the results of a trilateral research project carried out jointly by German, Israeli, and Palestinian institutions. The overall objective of the project was to develop and adapt models and tools for resource-preserving transport planning in the West Bank and the adjacent areas. Because of its high dynamics and the particular political circumstances, broader socio-economic and political considerations needed to be included in the analysis of present conditions and the exploration of future developments in this area. Compared to other countries, transport planning in Palestine is much more linked to sensitive issues such as security, Israeli settlements, bypass roads and checkpoints, which cannot always be separated in a clean way. To evaluate different policy options for transport planning, a modelling system has been developed consisting of a GIS database, integrated transport and environmental models and network extensions tools. The paper presents the integrated database and the modelling system developed, describes the scenarios implemented and compares the outcomes of the model runs with respect to their environmental and social impacts.

**Key words:** Transport planning, sustainability, models and tools, scenario evaluation

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**Sustainable Transport Planning for Israel and Palestine**


**Authors**

Franz Fürst †, Jad Isaac °, Isam Ishaq °, Jay Kaplan *, Hanna Maoh °, Ingo Petzold #, Lutz Plü mer #, Ilan Salomon *, Carsten Schürmann †, Klaus Spiekermann †, Michael Wegener †

° Applied Research Institute – Jerusalem (ARIJ)
Bethlehem, Palestine
Tel: 972 2 274 1889
Fax: 972 2 277 6966
E-mail: jad/hann@arij.org

# Institute for Cartography and Geoinformation, University of Bonn
D-53115 Bonn
Germany
Tel: +49 228 731756
Fax: +49 228 731753
E-mail: pluemer/petzold@mail.ikg.uni-bonn.de

* Department of Geography, Hebrew University Jerusalem
Israel
E-mail: amav@actcom.co.il, msilans@mscc.huji.ac.il

† Institute of Spatial Planning, University of Dortmund
D-44221 Dortmund
Germany
Tel: +49 231 755 2475
Fax: +49 231 755 4788
E-mail: ff/cs/ks/mw@irpud.rp.uni-dortmund.de

# 1 INTRODUCTION

The objective of the trilateral (German-Israeli-Palestinian) project "GIS-Based Models and GIS-Tools for Sustainable Transport Planning in Israel and Palestine" was the development and adaptation of GIS-based models and GIS tools for sustainable, i.e. resource preserving, transport planning in a regional context that, because of its high dynamics and the current political conditions, puts high demands on the flexibility of the methods to be applied.

Sustainable transport planning in Israel and the emerging Palestinian state faces major uncertainties and challenges (Garb, 1998). With rising income levels and car ownership, problems of road congestion, air pollution and traffic noise are expected to multiply in this densely populated region. While on the Israeli side massive road construction has replicated trends in other developed countries, the transport infrastructure in the Palestinian territories has been neglected for decades. The by-pass roads built by the Israeli authorities to link Israeli settlements with Israel and the restrictions on travel by Palestinians aggravate the problems of inequity in mobility. Air pollution generated by traffic in the conurbations of central Israel is transmitted to the West Bank due to prevailing air flows. These conditions have made transport planning proposals for Israel and the West Bank highly sensitive conflict-laden issues (see Fletcher, 1999).

The trilateral project was to contribute to the rational solution of these conflicts by providing state-of-the-art tools to assist in the rational assessment of the long-term equity and environmental implications of alternative transport planning policies.

The study area of the project comprised the West Bank and adjacent areas of Israel and Jordan; a larger area containing the major economic and social activities of Israel and the Palestinian territories was treated with less detail.

In view of the need to reach significant results in a short time, the focus was on the adaptation of existing rather than on the development of new models. ArcInfo (Environmental Systems Research Institute, Redlands, California, USA) was selected as the main geographic information system and EMME/2 (INRO Consultants, Montreal, Canada) as the transport modelling software.

Because of the high dynamics of transport planning and the particular political circumstances, broader socio-economic and political considerations needed to be included in the analysis of present conditions and the exploration of future developments in this area. Compared to other countries, transport planning in Palestine is much more linked to sensitive issues such as security, Israeli settlements, bypass roads and checkpoints, which cannot always be separated in a clean way.

# 2 MODELLING SYSTEM

## 2.1 Analytical framework

To evaluate scenarios of different policy options for forecasting environmental impacts of transport policy scenarios in the study area, a modelling system has been developed consisting of a GIS database, integrated transport and environmental models and network extensions tools.

Figure 1 is a diagrammatic representation of the structure of these models and tools as seen from the perspective of the user. Transport policies are entered at the Policy Analysis level subject to assumptions about political, economic, population and land use scenarios and are modelled using the integrated model system. The results of the simulations are converted to raster cells for processing in air quality or traffic noise models or to the triangulation used for the design of network extensions. The indicators produced by the transport model and the environmental sub-models are evaluated with respect to sustainability criteria such as equity, environment and efficiency.

The components of the integrated model system are:

- *ArcInfo*. The geographical information system ArcInfo is used to maintain, edit, plot and facilitate the spatial database. In that, ArcInfo serves as the core tool of the modelling system providing and receiving data to and from other (sub-)models, such as EMME/2, the Network Extension Tool and the Raster Module.
- *EMME/2*. The transport simulation model EMME/2 is used to model the specified scenarios to derive information on traffic flows, congestion and travel times.
- *Raster Module*. The results of the simulations are converted into ArcInfo format from which they are converted to raster cells for further processing in the Raster Module. This module is designed to simulate social and environmental impacts of the transport flows modelled.
- *Network Extension Tool*. Based on information provided by ArcInfo, the Network Extension Tool determines road optimum alignments for new road projects. The tool minimises a cost function between two or more locations by (i) integrating the digital terrain model and the network data by constrained Delaunay triangulation and (ii) automatic identification of intermediate or Steiner points.
- *Windfield Model*. A meso-meteorological model was developed to predict wind flows on an intermediate scale based on equations for horizontal motion, continuity, temperature and relative humidity within the atmosphere.
- *Photochemical Reaction Model*. This model simulates trace movements and photochemical reactions leading to ozone concentrations.

The indicators produced by the integrated model system are finally evaluated with respect to sustainability, i.e. with respect to equity, environment and efficiency.

The re-intensification of conflict between Israeli and Palestinians and the outbreak of the "Second Intifada" in the year 2000 had its impact on the project. Communication between the Israeli and Palestinian project partners was becoming increasingly difficult. These externally imposed difficulties have prevented the project to reach its ultimate goal to fully implement the model system as describe above and so to serve the planning practice in the West Bank and support the co-operation of Israeli and Palestinian researchers and planners in the joint pursuit of sustainable transport. Therefore, of the above comprehensive modelling framework, only the GIS database, the transport model, the interface between ArcInfo and EMME/2 and the network extension tool were implemented which are described below.

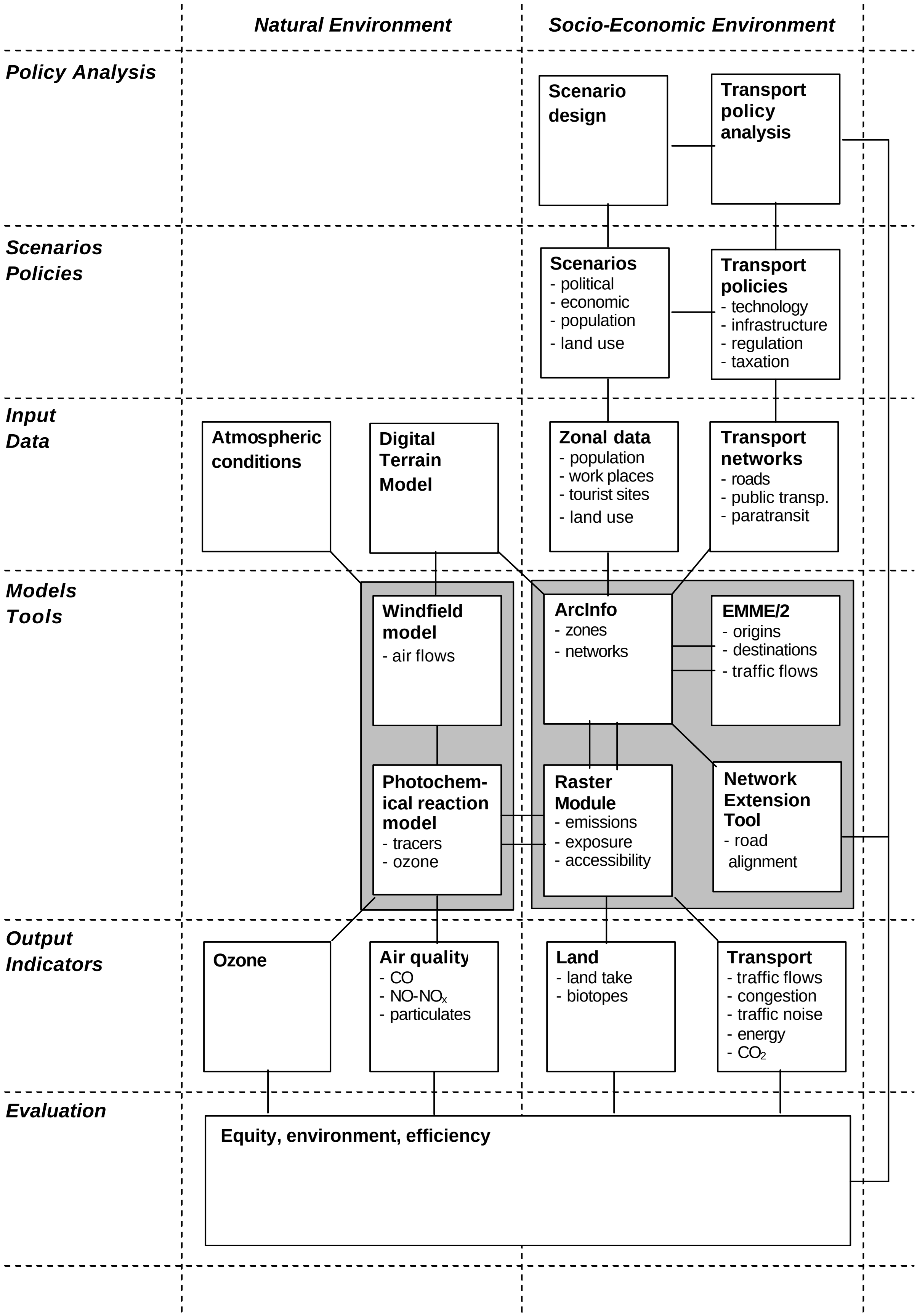


Figure 1. The integrated model system

### 2.2 Interface between ArcInfo and EMME/2

In order to take advantage of the superior data organisation of geographic information systems, a software interface for the two-way exchange of data between ArcInfo and EMME/2 was developed. The software performs two-way conversion between the different representations of network and zonal data of the two software packages. The interface consists of the following four conversion tools written in the ArcInfo Macro Language (AML) (Schauerte-Lüke et al., 1998):

- The macro *arc2emme* performs the transfer of network data from an ArcInfo coverage to EMME/2 batch file format
- The macro *emme2arc* performs the conversion of EMME/2 network data from EMME/2 batch file format to an ArcInfo coverage.
- The macro *tab2matrix* converts socio-economic data stored in ArcInfo Polygon Attribute Tables (PAT) to EMME/2 origin or destination matrices.
- The macro *matrix2tab* converts EMME/2 origin, destination and origin-destination matrices to ArcInfo Polygon Attribute Tables (PAT).

All conversion operations preserve all relevant information and attributes throughout the transformation process. All macros are executed from the Arc prompt within ArcInfo. Two additional macros serve as shell for the conversion tools:

- The macro *trnets* controls conversion from ArcInfo to EMME/2. It extracts scenario data from the ArcInfo database and calls the macros to convert them to EMME/2 format.
- The macro *putback* controls conversion from EMME/2 to ArcInfo. It extracts EMME/2 scenario results from the EMME/2 database and calls the macros to convert them to ArcInfo format.

The macros take account of different approaches of network representation within ArcInfo and EMME/2. A road network in ArcInfo consists of nodes and links. The alignment of the links can be described in great detail with up to 500 intermediate vertices. The ArcInfo network is based on real-world co-ordinates. Information about the network can be overlaid with other geographic information (e.g. land use). The user can design her own network information system with a relational database management system. Every spatial element has an attribute table with a set of predefined items used by the system. This table can be expanded with user-defined items. The EMME/2 network, too, consists of nodes and links. However, the EMME/2 network is only a generalised representation of the real network. The geographic position of the nodes is not defined in real-world co-ordinates, and the links do not represent the alignment between nodes. The whole network can be established in a model-specific co-ordinate system. Each link has its own attributes (e.g. number of lanes). Every element of the network has a special set of attributes. Moreover, collections of links such as transit lines may be defined. All roads - except one-way roads - are represented by two links. Nodes, links, turns and transit lines may have up to three additional user-defined attributes.

### 2.3 Network Extension Tool

As one result of the transport model, corridors between two or more location have been identified in which network extensions are to be planned to tackle problems of road congestion. The aim of the network extension tool then is to connect multiple locations with least construction and travel cost. Because shortest-path algorithms are not suitable to connect more than two locations, the proposed network extension tool introduces Steiner points, additional vertices to the network.

The developed algorithm is based on a two-level model which exploits the geomorphology of cost mountains by dividing the problem into smaller ones (divide-and-conquer technique) and using a essential extension of the Dijkstra single-source shortest-path algorithm to retrieve a restricted number of Steiner points.

Fixed local costs, such as topography, political restrictions or nature reserves, are represented in the cost surface by a homogenous constrained Delaunay triangulated model. Global costs, such as traffic volumes, are taken into account during the generation of paths between locations. The model supports the consideration of construction costs and of the travel costs supplied by EMME/2 via the EMME/2-ArcInfo interface.

*Geomorphology: passes*

Three different kinds of passes are extracted by the model. At first the 'normal' or 'significant' passes are extracted. These are passes satisfying the description of passes, i.e. they lie on a border between basins, present a local minimum on this border, and there exists a subsequence minimum–maximum–minimum–maximum. Next, 'insignificant' passes are extracted which do not lie on a border between basins but fulfil the remaining criteria. These passes are irrelevant for the solution. Finally, 'artificial' passes are extracted which fulfil all pass criteria except the subsequence on borders between two basins without 'normal' passes.

*Shortest paths: detail level*

The 'divide' step is performed by the extraction of basins. The lower level of the two-level model restricts the examination of basins. Each basin contains passes and further locations like towns to connect. For connecting three or more locations a method exploiting the Dijkstra shortest-path algorithm was developed: The shortest path from each location to all other vertices of the basin is calculated by taking local edge-cost (handicap), edge-length, slope, difference in altitude/z-value and the angle between the edges of the path into account. Eventually, each vertex has an array with the costs to each location of its basin. The sum of these costs represents the total cost from the vertex to all locations of the basin. The vertex with the lowest total cost in the basin is a Steiner point.

*Shortest paths: aggregate level*

The higher level of the two-level model represents the 'conquer' step. Now each basin is represented by a vertex. Neighbouring basins with common passes are represented by edges in the graph. The cost of each edge is determined during the lower-level phase as the cost between the Steiner points of the two basins and the least-cost pass between the two basins. There are special vertices representing basins which contain (one or more) locations to connect. The aim of the aggregate level is to connect these special vertices. The shortest paths and a Steiner point can be derived by applying the extended Dijkstra algorithm already used in the lower-level phase. Finally all vertices retrieve an array of costs to each special vertex. In contrast to the lower level, there are no passes to consider here. The vertex with the lowest total cost is a Steiner point.

*Interfaces*

Since the digital terrain model (DTM) data of the project are held in ArcInfo, the network extension tool supports the import of triangulated irregular network (TIN) data in ArcInfo's net-file format. Parameters, such as the weights of edge length, slope factor and angle factor and which nodes are to be connected are imported as well. The results of the network extension tool, the extended networks, are exported to ArcInfo employing the concept of simple features, a standardised interoperable data format defined by OpenGIS (Open GIS Consortium, 2001).

## 3 INTEGRATED DATABASE

The integrated database required for assessing transport policy scenarios is stored and maintained in form of ArcInfo coverages and consists of four components:

- A *digital terrain model* based on three panchromatic SPOT stereo scenes taken in October/November 1997 describing the mountainous relief of almost the entire study area at a very high level of detail and accuracy. The resolution of the DTM is 20 metres. There are extreme differences in elevation in the study region. Whereas cities such as Jerusalem, Hebron or Nablus are located between 600 and 800 m above sea level, the city of Jericho, only 25 km east of Jerusalem, is located nearly 400 m below sea level. Steep mountains and narrow valleys giving rise to potentially very high road gradients are major constraints for transport infrastructure planning. The DTM was mainly used for the development and implementation of the Network Extension Tool.
- An integrated and homogeneous *road network database* containing all major Israeli and Palestinian roads in the study area derived from several partial network databases of different origins, coordinate systems and precision. Roads are classified by categories such as motorways, main roads, regional roads and local roads. All traffic analysis zones are linked to the road network by connector links. The network database contains the current road network and future networks for each of the scenarios applied (see Section 4.1). Moreover, it became necessary also to introduce information on checkpoints, by-pass roads, restrictions for Palestinian vehicles and on the 'safe passage' corridors between the West Bank and Gaza due to the Oslo Accord. The checkpoints were classified according to their location with respect to the green line separating the West Bank from Israel and with respect to Jerusalem. Three classes were adopted: (i) checkpoints in close proximity to the Green Line. (ii) checkpoints on Road 60 allowing access to Jerusalem from the West Bank and (iii) the remaining checkpoints. The criteria for identifying restricted roads were as follows: (1) all roads in East Jerusalem, (2) roads giving access to and within Israeli settlements, (3) roads terminating at the border of the West Bank allowing access to Israel and (4) all roads in Israel.
- An integrated system of *traffic analysis* and *land use zones* consisting of 116 zones in the West Bank and 155 zones in Israel extracted from existing sources and made geometrically homogeneous with the digital terrain model and the road network database.
- *Socio-economic* data such as population, households, economically active persons, car ownership, work places and built-up areas. The database contains also forecasts of these data for the three scenarios to be analysed (see Section 4.1).

## 4 POLICY SCENARIOS AND SIMULATION RESULTS

### 4.1 Scenario definition

As mentioned above, the scenarios selected in the context of the trilateral project need to reflect the potential dynamics of the region. Unlike in most countries (e.g. in the European Union), which exhibit relatively stable trends in most relevant dimensions (e.g. demographic and economic development), the study area region can be characterised as experiencing quite dynamic changes in many relevant dimensions.

The following three major factors are suggested to determine the future situation of the study area (Salomon et al., 1998):

- *Peace*. The political situation in the study area is the most important factor distinguishing between adversary, cold or warm relationships between Israelis and Palestinians.
- *Population*. Population development in the region is a most important factor, as it directly affects the quantity of activities (mainly employment and education) and travel, as well as the demand for housing, which in turn generates changes in the distribution of travel and freight movement. Population growth is a quantitative dimension which can be grouped for the purpose of scenario building into a few categories (e.g. slow, fast, stagnant).
- *Economy*. The state of the economy in the Palestinian and Israeli areas. These can be assigned as being in a 'growth' mode, a 'stagnant ' state or a 'declining' state. Each of these three levels can be defined in terms of growth rates, based on available data. However, it is not necessary to make such quantitative definitions. The economic situation is likely to affect both the ability to invest in infrastructure as well as the growth in the use of cars.

Assuming a three-level categorisation for the above factors *Peace* and *Economy* and a two-level grouping of *Population*, 18 combinations can be identified, as shown in Table 1.

Table 1. Eighteen possible basic scenarios

| | Economic growth | | Economic stagnation | | Economic decline | |
|---|---|---|---|---|---|---|
| | Major population growth | Minor population growth | Major population growth | Minor population growth | Major population growth | Minor population growth |
| Adversary | 1 | 2 | 3 | 4 | 5 | 6 |
| Cold | 7 | 8 | 9 | 10 | 11 | 12 |
| Warm | 13 | 14 | 15 | 16 | 17 | 18 |

As the three dimensions described in the table are mutually dependent to some extent, some of the scenarios shown in the table can be screened out, as they are neither likely nor very interesting. For example, scenarios 1 and 2 are not likely, due to the dependence of economic growth on peaceful relationships in the study area. Given the likely interdependence between peace and economic growth, it is useful to select the diagonal cells as candidate scenarios for further analysis.

Population growth is also somewhat dependent upon the previous two dimensions. Population growth is more likely in peace than otherwise and more likely in a growing economy than otherwise. Hence, scenarios 5, 9 and 14 can be screened out. However, the most important determinant of the population growth is the issue of the returning Palestinian refugees. This will make the difference with regard to population growth. As this issue is to be dealt with in the political process in the study area, it is also possible that the population growth will be independent of the other two dimensions, implying that the remaining set of three scenarios will have to be expanded. So scenarios 6, 10 and 13 are chosen to explore for illustrative model runs.

These three general scenarios have been further specified with respect to commuting patterns, car ownership and public transport provision, networks attributes, accessibility, checkpoints, access to Jerusalem and access to roads and bypass roads. Finally, the three scenarios as summarised in Table 2 were developed.

The improvements to the road system assumed in the three scenarios are shown in Figure 2. It can be seen that they are similar in all three scenarios, except for the Separation Scenario in which a major new highway will be constructed linking Tel Aviv and Jerusalem north of the present motorway link. All three scenarios contain road projects already under or near construction, such as Road 6, a major limited-access highway that will serve as an outer ring and a north-south connection for the Tel Aviv area, the Jerusalem Ring Road, which will circle Jerusalem to shorten trips between Bethlehem and Ramallah without entering the centre of Jerusalem, and Road 80, a north-south highway in the eastern slopes of the West Bank.

Table 2. Definition of policy scenarios

| | Scenario I: **Status quo** | Scenario II: **Separation** | Scenario III: **Co-operation** |
|---|---|---|---|
| Palestinian population | Natural growth | Natural growth plus 300,000 returnees | Natural growth plus 250,000 returnees |
| Israeli population | Natural growth | 100,000 settlers evicted[a] | 200,000 Israeli settlers evicted[b] |
| Economic situation[c] | Decline | Stagnation | Growth |
| Road network changes | See Figure 4 | See Figure 4 plus safe passage | See Figure 4 plus safe passage |
| Accessibility to roads[d] | Limited | Checkpoints only along border | Minimal number of checkpoints |

Notes:

a These include all Israeli settlers scattered in the West Bank.

b This includes neighbourhoods in the area annexed by Israel like Gilo, Pisgat-Zeev, etc.

c This includes employment and car ownership.

d There is some level of congestion build-up next to checkpoints, which varies widely with changes in the security, and overall, it is not considered as a major problem.

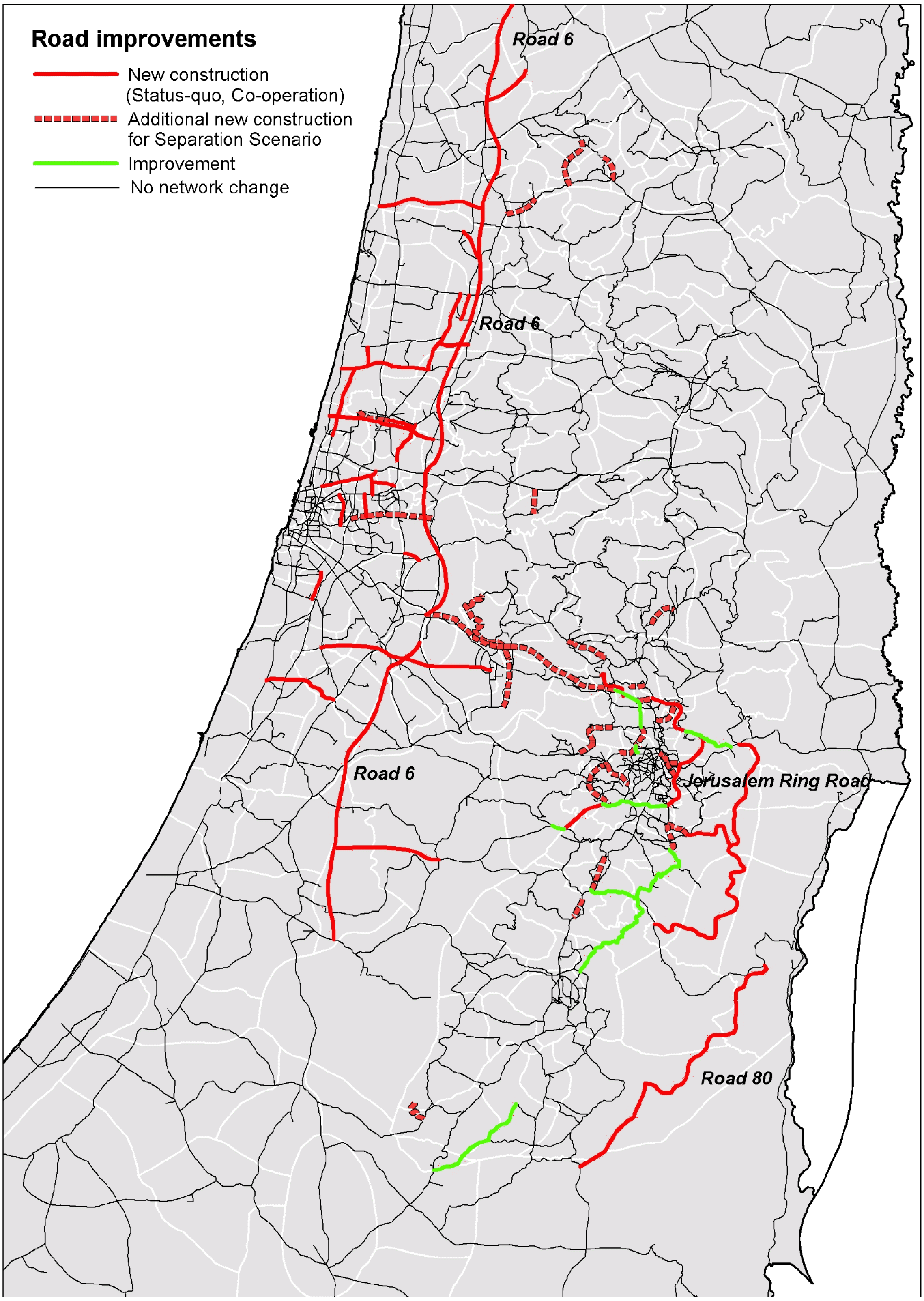


Figure 2. Road improvements in the three scenarios until 2020

Scenario I is called the ***Status-quo Scenario***. This scenario reflects the current status if it is prevail until the year 2020. This scenario is considered as the benchmark for the analysis. This scenario assumes a natural growth in the Palestinian and Israeli population of the study area. As in the present time, no major change in employment trends is taking place; thus the scenario assumes decline in the economy. Road network development is assumed to take place in this scenario as in the other two scenarios: Road 6, the Jerusalem ring road and Road 80 are assumed to exist in 2020. Restrictions on roads to Palestinian vehicles will still exist, and there will be a large number of checkpoints resulting in a high level of delay on a number of road links.

Scenario II is called the ***Separation Scenario***. This scenario assumes cold relations in which a rigid boundary between the Palestinian territories and Israel exists. The Palestinian population is assumed to grow naturally. In addition, some 300,000 Palestinian returnees are assumed to be distributed evenly across the Palestinian urban centres of the region. The scenario also assumes that 100,000 Israeli settlers are evicted from the West Bank. Since the region is assumed to have a high level of Palestinian population in the year 2020, the economic situation is assumed to go in the stagnation mode. Road network improvement in this scenario is the same as in the Status-quo Scenario except that a second, more northern connection between Tel Aviv and Jerusalem will be constructed and the safe passage corridors between the West Bank and Gaza will exist. Unlike the Status-quo Scenario, checkpoints within the West Bank no longer exist, however, the checkpoints along the border providing access to Jerusalem and Israel have medium delays.

Scenario III is the ***Co-operation Scenario***. This scenario assumes friendly relations between Palestinians and Israelis. The scenario expects 300,000 Palestinian returnees and evicts 200,000 Israeli settlers from the West Bank. Unlike the Separation Scenario, the Co-operation Scenario assumes economic growth resulting from the low restriction on accessibility as all checkpoints and road restrictions are removed in this scenario. Employment levels and car ownership are expected to increase. The same improvements in the road network are expected to take place as in the Status-quo Scenario except that the safe passage corridors will exist.

### 4.2 Simulation results

The three scenarios as described in the previous section are extracted from the GIS database and simulated with the transport model. The results in terms of transport flows, traffic safety and travel times can be described as follows:

*Transport flows*

Total morning peak hour trips for the Israeli population accessing the road network as coded in the road network database total about 110,000 passenger-car equivalents (PCE) per hour. This number is to rise to over 213,000 PCE per hour in the forecast year 2020. This increase is due to the assumed natural population growth of the Israeli population. These trip levels are equivalent to rates of 0.06 PCE per hour per household today, rising to 0.084 PCE per hour per household in the future, with the bulk of the increase due to the forecast increase in vehicle availability and use. Similarly, the Palestinian population travel patterns are forecast to intensify from rates of 0.02-0.03 today to 0.04-0.06 in the forecast year.

Figure 3 presents transport flows in terms of link volumes in PCE for the base year separately for the Israeli and Palestinian population. It is evident that the highest link volumes can be observed in the Tel Aviv area and on the freeway linking Tel Aviv and Jerusalem. There is also a considerable amount of Israeli travelling around Jerusalem. However, Israeli travel in the West Bank is almost negligible, with the exception of the route Jerusalem-Hebron-Be'er Sheva. This is also the most travelled route for Palestinians in the southern part of the West Bank. North of Jerusalem, that route continues linking Jerusalem with Ramallah and Nablus. As to be expected, link volumes in the West Bank are by far lower than those in Israel.

The overall model results indicate that the planned improvements to the road system in combination with growing population figures for both Israeli and Palestinians as reflected in the model comprise an addition of 8-11 % to the lane-kilometres of the road network (from 17,560 lane-km today to 19,000-19,500 lane-km depending on the scenario). The commensurate increase in vehicle-kilometres travelled (VKT) under the Co-operation Scenario is 43% (from 642,700 VKT today to 917,000 VKT in 2020). The other scenarios are expected to result in smaller increases in total travel due to the relative spatial segregation of the population groups: The Status-quo Scenario for the year 2020 results in a total of 662,000 VKT (3% increase), and the Separation Scenario in a total of 706,000 VKT (10% increase).

However, as Figures 4-6 show, these differences are reflected in different spatial patterns. A comparison between the Separation and Status-quo Scenarios (Figure 4) reveals that most of the differences take place in the Tel Aviv-Jerusalem corridor where a huge shift in transport flows from Freeway 1 to the newly created northern connection between Tel Aviv and Jerusalem can be observed. A similar phenomenon can be observed for the link between Bethlehem and Hebron. Considering the safe passage corridors between the West Bank and Gaza, it is expected that the traffic volumes will be reduced in the Separation Scenario. For all other links, only small differences between these two scenarios are expected. This pattern reflects the fact that in the Separation Scenario only limited exchange between the Israeli and Palestinian population groups is possible and that movements of people and goods are hindered by checkpoints and political obstacles.

The highest increase in VKT is expected for the Co-operation Scenario, and this increase is evenly distributed across all roads in the study area (Figure 5). Almost all major roads in Israel and the West Bank will experience increasing link loads, in particular roads around Jerusalem. This is consistent with expectations as when political, military and social barriers between the two population groups are torn down, this will lead to increasing transport flows in all areas. However, in the Israel areas planned improvements to the national road system (including Roads 6, 7, 45, 55, 431, 461, 471, 531, etc.) are expected to ameliorate the adverse effects of the additional traffic loads. In the Palestinian areas, local congestion problems can be expected, and additional improvements to the road system will become necessary.

The spatial patterns that appear when the Co-operation and Separation Scenarios are compared are not that clear (Figure 6). Most evidently, the greatest differences can be seen in the Tel Aviv-Jerusalem corridor. In the Co-operation Scenario, the southern link (Road 1) will be clearly more frequented than the northern link, which had higher link loads in the Separation Scenario. Interestingly, the roads in the West Bank have slightly higher traffic loads in the Separation Scenario, while the roads in Israel show higher traffic flows in the

Co-operation Scenario. This may lead to the hypothesis that in the Co-operation Scenario people (in particular Palestinian people) are more attracted to travel to Israel than within the West Bank, whereas in the Separation Scenario traffic between Palestinian and Israeli areas is obstructed so that movements of Palestinians are limited to the West Bank.

*Traffic safety and travel times*

A primary concern with the intensification of traffic is the issue of traffic safety. Traffic safety issues in the West Bank can be broadly characterised by three primary contributing factors: high travel speeds (especially in the western half of the area where more flatter terrain and long travel distances encourage higher speeds), dense built-up areas (where traffic congestion and heavy foot and bicycle traffic compound with poor road hierarchy to result in more chances for conflict), and finally the poor condition of roads (especially on the eastern slopes of the region, where steep topography results in winding roads and safety problems due to poor design and maintenance and sight-line issues).

An example of such safety problems indicated by the model results is the Wadi-al-Nar route connecting Bethlehem and Ramallah (see also Maoh and Isaac, 1999). Today restrictions on the travel of Palestinian vehicles through Jerusalem necessitates vehicles to take this more circuitous route on the eastern slopes of the Judean Mountains through the steep gorge of Wadi-al-Nar. In scenarios where travel through Jerusalem is restricted, hourly traffic volumes on this route are forecast to increase from 400-600 PCE today to 1,200-1,600 in 2020. In scenarios where travel through Jerusalem is allowed as a route from Bethlehem to Ramallah, traffic volumes in Wadi-al-Nar are expected to increase less precipitously to 800-1,200, mostly serving local access to growing neighbourhoods of East Jerusalem. The eastern part of the Jerusalem ring road is expected to provide additional needed capacity for this travel corridor.

Besides safety concerns, also travel times between Bethlehem and Ramallah are of interest for Palestinian people. In scenarios where they are allowed to travel through Jerusalem, the travel time between Bethlehem and Ramallah is expected to be half or even less of that travel time using the Wadi-al-Nar route, even though there will be congestion or waiting times at traffic lights in Jerusalem itself. However, this expected reduction in travel time between Bethlehem and Ramallah will also have considerable impacts on social contacts of Palestinians and on Palestinian economy.

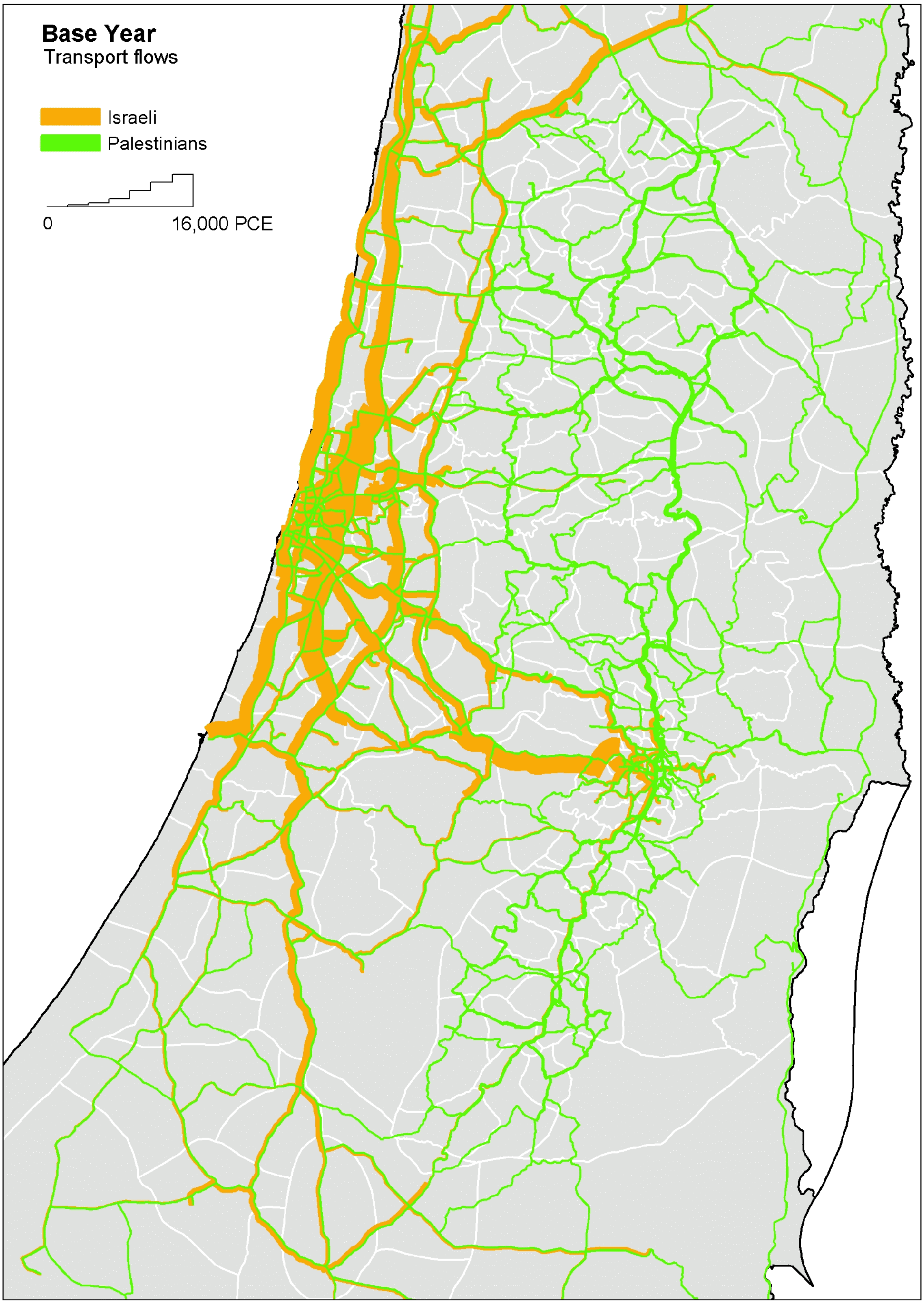


Figure 3. Modelled transport flows in 2000

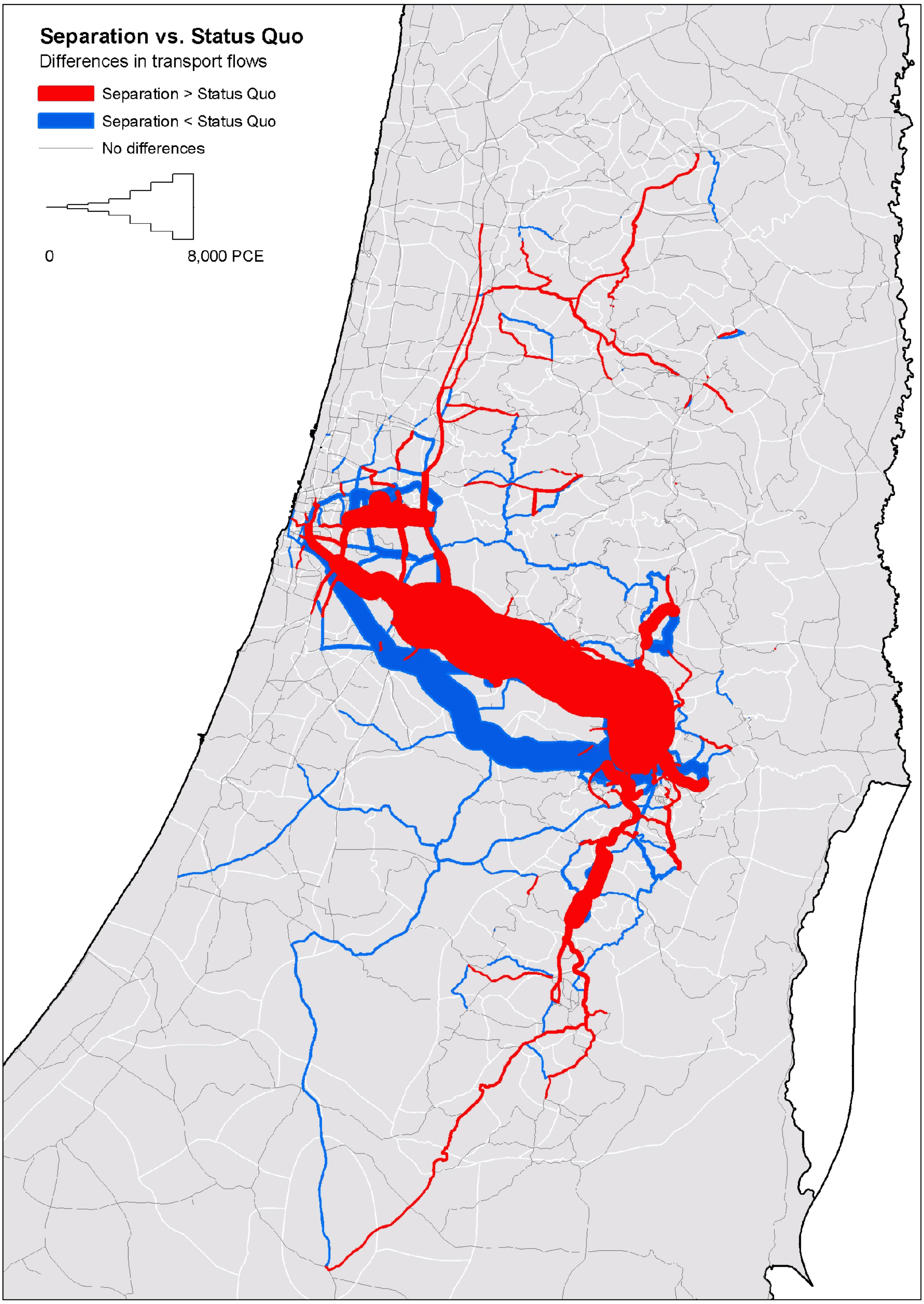


Figure 4. Differences in link volumes: Separation vs. Status quo

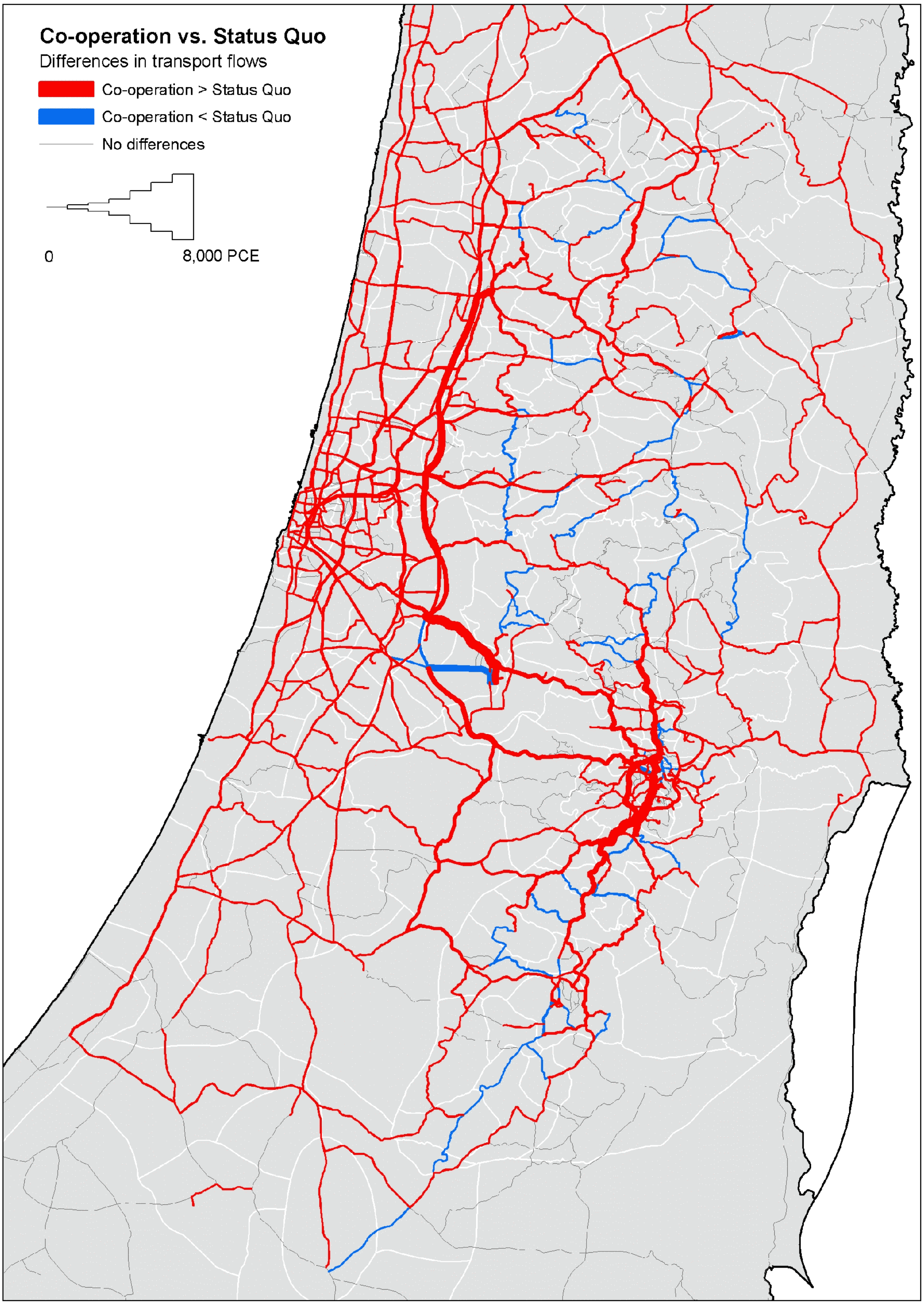


Figure 5. Differences in link volumes: Co-operation vs. Status quo

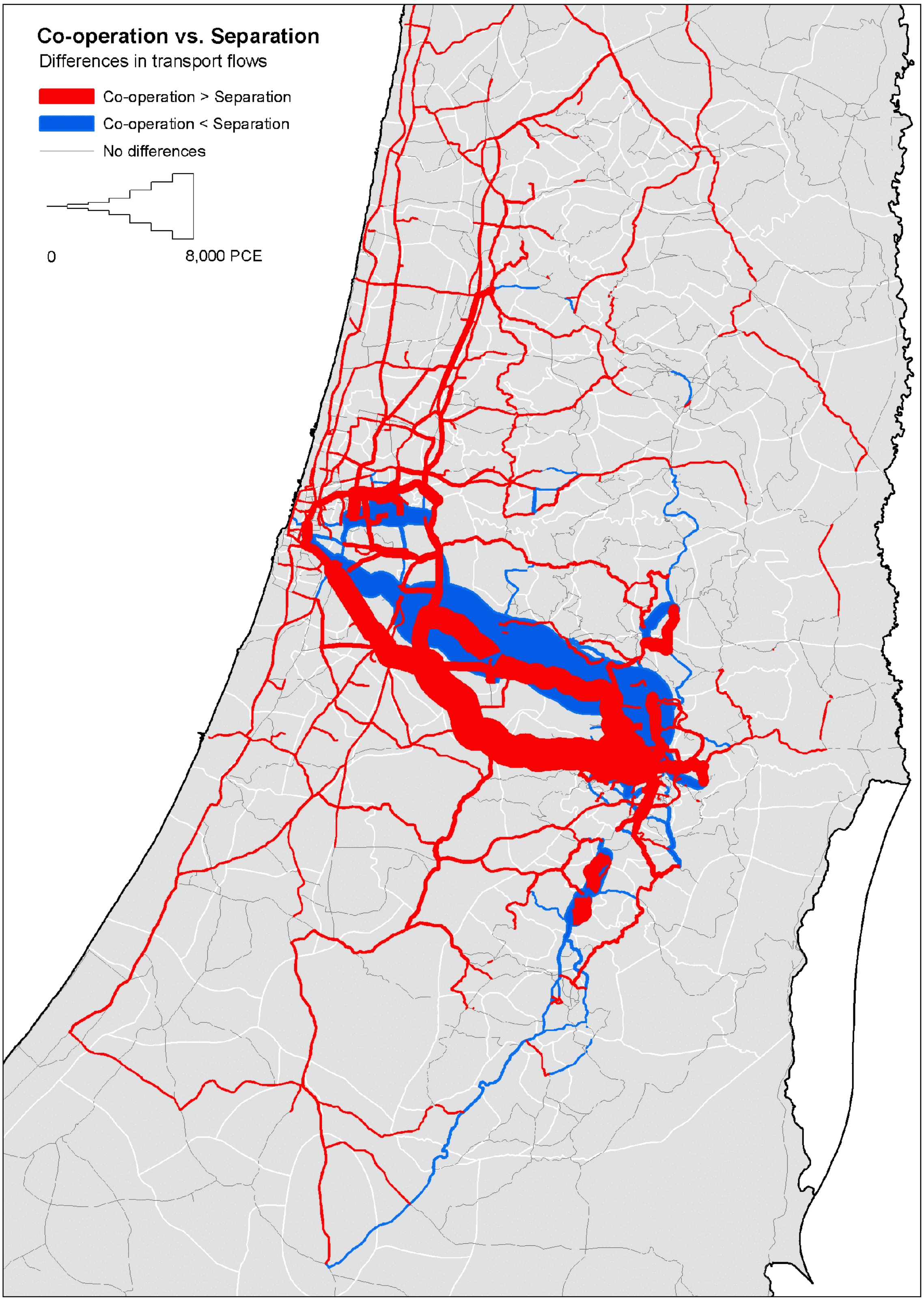


Figure 6. Differences in link volumes: Co-operation vs. Separation Scenario

## 5 CONCLUSIONS

The slowing down of the Peace Process during the year 2000 has had its effects on the project. Although significant progress in achieving the technical tasks has been made, not all of the initial objectives could be accomplished. The individual components of the envisaged GIS-based methodology for sustainable transport planning in the West Bank have all been developed and tested and at least partly applied together in a pilot application.

The project was successful in establishing a methodological framework for a linkage between a GIS and a transport model and environmental impact models. In particular the two-way macro-language interface between ArcInfo and EMME/2 represents a major advance over previous isolated applications of GIS and models in transport planning. Also the network extension tool developed is potentially a significant step beyond conventional ways of designing transport network extensions.

However, the integrated framework consisting of ArcInfo, EMME/2, the ArcInfo-EMME/2 interface, the network extension tool and the environmental impact submodels has not been implemented in its entirety.

Nevertheless the pilot applications of the methodology presented in this paper demonstrate that the components of the methodology function together and produce meaningful results. The results of the simulations of three policy scenarios confirm that the hypothesis that peaceful co-existence would give rise to a more spatially distributed and hence more equitable and more sustainable pattern of movements. However, the selection of policy scenarios is more limited than initially intended. Original plans to examine also more fundamental policy options, both in terms of political and socio-economic scenarios and in terms of transport infrastructure alternatives could not be implemented. Nevertheless, it must be counted as a significant success that the Israeli and Palestinian partners were able to reach consensus about a common set of policy scenarios, something hardly imaginable in the frosty political climate of today.

So a number of unachieved tasks still remain that should be addressed here:

- First priority on a future research agenda would have the completion of the integration of the modelling framework as it is illustrated in Figure 2.
- This would include the full integration of the network extension tool into the software system and the linkage between the GIS and the transport model with the already existing environmental submodels.
- The extension of the network database to include all bus lines and the existing shared-taxi paratransit system would allow to investigate environment-friendly transport policy options.
- The set of policy scenarios examined should be greatly extended to include different combinations of transport policy packages and political and socio-economic scenarios.


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