Distr.
GENERAL
E/ESCWA/TRANS/2000/2/Add.1
11 December 2000
ORIGINAL: ENGLISH

ECONOMIC AND SOCIAL COMMISSION FOR WESTERN ASIA

METHODOLOGICAL FRAMEWORK FOR THE INTEGRATED TRANSPORT SYSTEM IN THE ARAB MASHREQ (ITSAM-FRAMEWORK)

VOLUME II: A POLICY-SENSITIVE MODEL FOR PREDICTING INTERNATIONAL FREIGHT FLOWS (TRADE)

United Nations
New York, 2001

01-0175

Preface

This volume comprises an integral part of a study on the methodological framework for the formulation and analysis of policies for the development of the Integrated Transport System in the Arab Mashreq (the ITSAM-FRAMEWORK), carried out under the 2000-2001 work programme for the Transport Section of the Sectoral Issues and Policies Division of ESCWA. The main contributors to this volume include Mr. Nabil Safwat, Chief of the Transport Section and direct supervisor of the study, and Mr. M. Kamal Hasan, First Economic Affairs Officer in the same Section from March to July 2000. The model developed in this study—the international freight simultaneous transportation equilibrium model (IFSTEM)—is essentially an extension and adaptation of the simultaneous transportation equilibrium model (STEM), developed earlier by Safwat (1982) and applied to various transport networks by a number of researchers including Safwat and Hasan. The study was conducted under the general supervision of Mr. Ahmed Farahat, Chief of the ESCWA Sectoral Issues and Policies Division.

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EXPLANATORY NOTES

The following symbols have been used in the tables throughout the publication:

Two dots (..) indicate that data are not available or are not separately reported.

A dash (—) indicates that the amount is nil or negligible.

A hyphen (-) indicates that the item is not applicable.

Parentheses ( ) indicate a deficit or decrease, except as otherwise stated.

A slash (/) indicates a school year or a financial year (e.g., 1981/82).

Use of a hyphen (-) between dates representing years, for example, 1981-1983, signifies the full period involved, including the beginning and end years.

Details and percentages do not necessarily add up to totals, because of rounding.

In both the text and tables of the study, references to "dollars" ($) indicate United States dollars, unless otherwise stated.

Bibliographical and other references have, wherever possible, been verified.

Introduction

The main objective of the ESCWA secretariat is to increase the effectiveness and efficiency of sustainable social and economic development processes in Western Asia by developing and strengthening regional cooperation and integration. One of the most important issues within this context is intraregional trade. In 1997 exports from ESCWA member countries totalled US$ 124 billion (2.36 per cent of world exports); the six Gulf States, namely, Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates, accounted for 87 per cent (US$ 108 billion) of the region's export total. During the same year, imports to the ESCWA region amounted to US$ 109.5 billion (2.36 per cent of world imports), with the Gulf countries accounting for 69.44 per cent (around US$ 75.96 billion) of the total for the region. The average export-import ratio was 1.42 for the Gulf countries and 0.48 for the other seven ESCWA members (those with more diversified economies). Trade between the ESCWA members remained relatively low: between 1990 and 1997 their export share fell from 10.9 to 8.6 per cent, and their import share rose from 9.1 to 10.4 per cent. A similar situation is observed for other Arab countries. The Arab Monetary Fund and other financial institutions made a considerable effort to increase these percentages by establishing a US$ 500 million fund to finance intraregional trade. However, the demand for such support was weak owing to the complexity of border procedures and formalities and the imposition of high tariffs between ESCWA member countries (ESCWA, 1997; 1999).

The ESCWA secretariat recognizes the important role transport plays in supporting sustainable development processes. The integration of transport networks, the easing of border procedures and formalities, and the reduction or elimination of tariffs are vital to facilitating the movement of goods and passengers within and between ESCWA member countries and between those countries and the rest of the world. Effective transport connections can serve markets and communities and create or strengthen links between centres of production and consumption. In addition, facilitating regional and international transport flows through the member States is likely to contribute significantly to improving the international trade competitiveness of local industrial and agricultural products and services.

In the present context of increasing globalization, the ESCWA secretariat is playing a key role in promoting an integrated transportation system linking all the countries of the region. The system is designed not only to facilitate intraregional trade and promote greater economic integration, but also to connect the ESCWA members with neighbouring countries and regions and further integrate Western Asia into the global economy. This is an essential component of efforts to achieve sustainable socio-economic development and prosperity in an era characterized by interconnectedness. Below is a brief description of ESCWA activities in this regard, including a detailed presentation of the model developed in the study and its application to a prototype transport network in the region.

I. THE INTEGRATED TRANSPORT SYSTEM IN THE ARAB MASHREQ

During the twentieth session of ESCWA, held at United Nations House in Beirut on 27 and 28 May 1999, the Commission, in its resolution 221 (XX) of 27 May 1999, took note of the contents of the summary reports submitted by the subsidiary bodies of ESCWA to that session, including, by implication, the statement on the adoption and development of an Integrated Transport System in the Arab Mashreq (ITSAM), incorporated in the "Report on the first session of the Committee on Transport" (E/ESCWA/C.1/20/7/Add.6). Conceptually, the contribution of the ESCWA secretariat to the development of ITSAM comprises the following three basic components:

(a) ITSAM-NETWORK, an integrated transport network;
(b) ITSAM-INFOSYS, an associated information system;
(c) ITSAM-FRAMEWORK, a methodological framework for issue analysis and policy formulation.

The above-mentioned statement included a declaration by member States regarding the development of ITSAM and the adoption of an integrated transport network for that system in the region. The first edition of the ITSAM-NETWORK map, incorporating the statement in its entirety, was officially approved and presented at the Commission's twentieth session and was published in June 1999; its component networks are shown in annex figures I-IV.

With regard to ITSAM-INFOSYS, the second major component, several schemes at various stages of maturity have been proposed by regional institutions, and prospects for their implementation will be determined. A working paper by A. Farahat (1999) provides details on the purpose, scope and structure of this information system. The paper outlines the harmonization measures that will have to be undertaken to pave the way for subsequent stages of system development. Annex figures V and VI show the basic concepts and components of the envisaged ITSAM-INFOSYS.

In 1999 N. Safwat produced a working paper outlining the general characteristics of a methodological framework for ITSAM (the ITSAM-FRAMEWORK). The paper also offers a detailed explanation of the main assumptions, variables, relationships, groups and organizations to be considered in the analysis. At the centre of this framework is a process for predicting the impacts of alternative policy scenarios of the system's demand and performance on the system's major groups of users, operators, owners and other concerned parties. The results include predictions of equilibrium transport demands and performance levels for the integrated network. The effects on major groups can be forecast through the use of a set of impact models. Annex figure VII shows the methodological framework for ITSAM development.

The present study focuses on modelling the simultaneous prediction of demand (traffic flows) and performance (times and costs) of freight within ITSAM. The model is referred to as the international freight simultaneous transportation equilibrium model (IFSTEM) for reasons related to basic characteristics and assumptions associated with it. As indicated above, this represents a central component of the ITSAM-FRAMEWORK.

II. IFSTEM MODELLING

A. LITERATURE REVIEW

The prediction of multi-commodity freight flows on a multimodal network has attracted substantial interest in recent years. The prediction of passenger flows on multimodal urban transportation networks has been studied extensively, and many of the research results have been applied at the practical level (Safwat and Walton, 1988; Safwat and Hasan, 1989; Safwat, 1987a, 1987b; Safwat and Magnanti, 1988; Hasan, 1991; Hasan and Al-Gadhi, 1998; Hasan and Safwat, 2000; Florian, 1984, 1986); however, the study of freight flows at the national, regional and international levels, perhaps owing to inherent difficulties and complexities, has received less attention. A good review of freight transport modelling may be found in Friesz and Harker (1985). Below is a brief review based on an article by Guélat, Florian and Crainic (1990).

The first category of models studied comprehensively in the past for the prediction of interregional freight flows is the spatial price equilibrium model and its variants. The model, developed initially by Samuelson (1952) and later extended by Takayama and Judge (1964, 1970), then by Florian and Los (1982) and Friesz, Tobin and Harker (1983), has been used extensively to analyse interregional commodity flows. Models within this class simultaneously determine flows between producing and consuming regions and selling and buying prices. The transportation network is usually modelled simply (as a bipartite network), and the models rely largely on the supply and demand functions of the producers and consumers respectively. The calibration of such functions is essential to the application of these models. Transportation costs are unit costs or may be functions of the flow on the network. There have been few multi-commodity applications of this class of models; the majority of applications have been carried out in the agricultural and energy sectors in an international or interregional setting. In any case, it is not this class of models that is the main focus of the present study.

Freight network equilibrium models constitute the second category to be considered in the current context. These models allow the prediction of multi-commodity flows on a multimodal network; the physical network is modelled at a level of detail appropriate for a nation or large region and physical facilities are represented with relatively little abstraction. The demand for transportation services is exogenous and may originate from an input-output model, if one is available, or from other sources, such as observed demand or the scaling of observed past demand (in the proposed IFSTEM model endogenous transportation demand will be considered). The choice of mode or subsets of modes used is exogenous, and intermodal shipments are permitted. In this sense, these models may be integrated with econometric demand models as well. The emphasis is on network representation and the proper representation of congestion effects in a static model designed to serve comparative studies or discrete time multi-period analyses.

The first significant predictive multimodal freight network model was developed by Roberts (1966) and later extended by Kresge and Roberts (1971). It came to be known as the Harvard-Brookings model. Only the behaviour of shippers is taken into account. It is assumed that constant unit costs apply, and each shipper chooses the shortest path for movement from an origin to a destination; the traffic moving between an origin and a destination is determined by a simple distribution submodel. The model relies on a fairly simple "direct link" representation of the physical network, and congestion effects are not considered. The model has been applied to the transport network of Washigton, D.C.

The multi-state transportation corridor model, developed later (McGinnis, Sharp and Yu, 1981; Jones and Sharp, 1979; and Sharp, 1979), goes a step further in representing an explicit multimodal network but does not take the effects of congestion into account. The first model to consider congestion effects and shipper-carrier interactions is that of Friesz, Viton and Tobin (1985). A review of shipper-carrier models, both sequential and simultaneous, is provided by Friesz and Harker (1985). The freight network equilibrium model (FNEM) developed by Friesz, Gottfried and Morlok (1986) is the first model considering congestion phenomena to actually be applied in the field of freight transport. This is a sequential model that incorporates two network representations: an aggregate network perceived by users, which serves to determine the carriers chosen by the shippers; and more detailed separate networks for each carrier, where commodities are transported at minimum total cost. Harker and Friesz (1986a, 1986b) generalized the work of Friesz, Viton and Tobin (1985) by incorporating variable demand functions in the shippers' submodels.

They combine the variable demand modelling approach of spatial equilibrium models with a detailed description of the behaviour of shippers and carriers, using mathematical formulations that have yet to be tested through practical application.

Guélat, Florian and Crainic (1990) developed a multimodal multi-product network assignment model that does not consider shippers and carriers as distinct actors in freight shipment decisions. The level of aggregation appropriate for the strategic planning of freight flows, where origins and destinations correspond to relatively large geographical areas, leads to the specification of supplies and demands for all products considered, which represent the services provided by all the individual shippers for the same product. The model assumes that goods are shipped at minimum total generalized cost; this approach is particularly appropriate in cases in which certain products are captive to a mode or subset of modes owing to service availability or regulation. In other situations (such as those characterized in the present study), in which modes compete for the shipment of products, a decision may be made to include in the generalized cost function certain components that reflect shippers' objectives (for example, costs, time delays or other relevant factors), though it should be kept in mind that shippers, in this context, are aggregated by origins. The multimodal aspects of this model are accounted for in the network representation chosen, and the multiproduct aspects are accounted for in the formulation of the predictive model and are taken advantage of in the solution procedure.

In his 1982 doctoral dissertation, Safwat introduced the simultaneous transportation equilibrium model (STEM). An application of STEM to the intercity transport system in Egypt covered both passenger and freight movement. In this model, the generation of trips in a region is incorporated via a specific non-linear function including transportation costs (see also Safwat and Magnanti, 1988). For the Egyptian application, Safwat represented producer and consumer behaviour using this specific trip-generation function, condensing their decision-making processes into one known functional relationship. In practice, STEM has been applied to a few real-world transportation systems. Earlier applications covered intercity passenger travel in Egypt (Safwat, 1987a, 1987b) and the urban transportation network of Austin, Texas, in the United States (Safwat and Walton, 1988). More recently the model was applied to the urban transportation networks of Riyadh (Hasan and Al-Gadhi, 1998) and Tyler, Texas, (Hasan and Safwat, 2000). Moavenzadeh, Markow, Brademeyer and Safwat (1983) included an extended version of STEM as a central component of a comprehensive methodology for intercity transportation planning in Egypt. This methodology was used in several case studies involving multimodal transportation of passengers and freight in Egypt in 1986.

The international freight simultaneous transportation equilibrium model (IFSTEM) developed in the present study is based on STEM (Safwat, 1982; Safwat and Magnanti, 1988) and adapted to freight transport using some concepts of the Guélat, Florian and Crainic model (1990) and the Friesz, Gottfried and Morlok model (1986). IFSTEM is a central component of the ITSAM-FRAMEWORK being developed by ESCWA (see Safwat, 1999, for a detailed description of this framework).

B. Network representation

The physical network infrastructure represented by IFSTEM supports the transportation of several products by several modes. A product is any category of commodity (a collection of similar products), goods or passengers that generates a link flow specifically associated with it. A mode is a means of transportation with particular characteristics, such as vehicle type and capacity, as well as a specific cost function.

A base network consists of physical nodes representing capitals, cities, border points, seaports and airports, as well as the physical links that connect those nodes for different types of modes. Represented as well in the model are various types of administrative and logistical operations (ALOs) at origins, destinations, border points, seaports and airports; these ALOs include export and import procedures, transit-in (entry) and transit-out (exit) procedures, pre-import and pre-export procedures (those not performed at the border point itself, and transfer operations). ALOs often involve dummy links that connect some of the physical nodes with fictitious (artificial) nodes.

Since each commodity can be transported by a specific mode or set of modes depending on commodity characteristics, a network for each commodity type has been created under IFSTEM. Each commodity type r has its own network that can be defined by a set of nodes N^r and a set of links A^r for a combination of modes and operations, as follows:

$$A^r = \left[\left(\bigcup_{m(r)} A^{m(r)} \right) \bigcup \left(\bigcup_{o(r)} A^{o(r)} \right) \right] \text{ and } N^r = \left[\left(\bigcup_{m(r)} N^{m(r)} \right) \bigcup \left(\bigcup_{o(r)} N^{o(r)} \right) \right] \quad (1)$$

where

$m(r)$ = a set of mode types possible for commodity type r (combinations of road, rail, air and/or maritime modes),

$o(r)$ = a set of ALO types for commodity type r (combinations of export, import, transit-in, transit-out, pre-export, pre-import and/or transfer operations), and

$\bigcup$ = the union operator of two or more sets.

The creation of operation links for each commodity r depends on the origin and destination of this commodity. The network is thus further decomposed into origin-destination (O-D) combinations; each O-D pair for commodity r has its own network. Annex figure VIII shows a multimodal O-D pair network in which each transport mode has its own network including unique node and link identification numbers. If at any node of any modal network that connects the given O-D pair there is the possibility of transfer to another modal network, this is represented by an artificial transfer link between the two modes. A physical modal origin node is connected to an artificial node by an artificial link that represents the pre-export operation of the given commodity at the given origin. Similarly, any physical modal destination node is connected to an artificial node by an artificial link that represents the pre-import operation of the given commodity at the given destination. All of the artificial modal origin nodes are connected to a super artificial origin node, and all of the artificial modal destination nodes are connected to a super artificial destination node through artificial dummy links that entail no cost.

According to the representation above, a specific commodity flowing between a given O-D pair can begin from its super artificial origin and move through a multimodal network until it reaches its super artificial destination. The network representations for export, import, transit-in and transit-out ALOs for land border points are shown in annex figure IX. Part (a) of the figure shows part of a directed road network at a border between country X and country Y, and parts (b) and (c) show ALOs involving node 102 in country X and node 200 in country Y. Part (b) shows a possible directed ALO from country X to country Y based on the creation of the following artificial nodes and links:

(a) At node 102, two artificial nodes (10211 and 10214) and two artificial links (102-10211, which represents the export operation, and 102-10214, which represents the transit-out operation) were established. Then, two links (10211-200 and 10214-200) were created; either of these represents the physical link 102-200 in part (a). Since either export or transit-out will occur, the commodity will flow along either the 102-10211-200 or the 102-10214-200 path;

(b) At node 200, two artificial nodes (20012 and 20013) and two artificial links (200-20012, which represents the import operation, and 200-20013, which represents the transit-in operation) were established. Then, two links (20012-201 and 20013-201) were created, either of these represents the physical link 200-

A_j^r = a composite measure of the effect that socio-economic variables exogenous to the transport system have on the number of tons of commodity r imported at destination j.

The quantities θ_i^r and θ_{iw}^r for $w = 1, 2, ..., W$ are coefficients to be estimated, where $\theta_i^r > 0$.

During the time period required to achieve the short-run equilibrium predicted in the model, socio-economic activities in the system will remain essentially unchanged; the composite effect A_j^r of these activities is assumed to be a fixed constant. Thus, for a specified socio-economic system, the observed utility of exporting commodity r from origin i to destination j, V_{ij}^r, depends solely on the perceived delivery cost, u_{ij}^r, as follows:

$$V_{ij}^r = V_{ij}^r(u_{ij}^r) \tag{5}$$

Exporters are utility maximizers; therefore, within each O-D pair exporters compete with one another for limited transportation facilities while trying to minimize their own delivery costs. A Wardropian user equilibrium among exporters exists when no exporter acting unilaterally can decrease his delivery cost (Wilson, 1970). At equilibrium, the delivery costs u_{ij}^r on all used paths are equal to or less than those on unused paths between a given origin-destination (O-D) pair.

3. *Accessibility*

In the context of freight transport, accessibility can be defined as some composite measure that describes the characteristics of a group of export alternatives as they are perceived by a particular exporter. In the context of the random utility theory of exporter behaviour, which assumes that utility functions are random and exporters are utility maximizers, accessibility can be measured by the expected maximum utility to be obtained from a particular export choice situation. On this basis, in the present study accessibility is defined as a composite measure of transportation system performance and socio-economic system attractiveness as perceived by a typical exporter of a given commodity from a given origin, as follows:

$$S_i^r = E\left[\max_{j \in D_i^r} v_{ij}^r\right] \tag{6}$$

where

S_i^r = the accessibility of the exporter of commodity r at origin i, and

E = the expectation operator.

If it is assumed that the error terms ε_{ij}^r of the random utility functions v_{ij}^r are independent and identically distributed as a type I extreme value probability distribution (Gumbel, 1958), accessibility can be expressed as follows (see Ben-Akiva and Lerman, 1985):

$$S_i^r = \ln \sum_{j \in D_i^r} \exp(V_{ij}^r) \qquad \text{for all exporters} \tag{7}$$

In equations (6) and (7) the accessibility S_i^r of the exporter of commodity r at origin i depends solely on the perceived delivery cost, u_{ij}^r, for all destinations feasible for importing commodity r from origin i; that is,

$$S_i^r = S_i^r(u_{ij}^r : j \in D_i^r) \tag{8}$$

Equation (7) assumes that the value of S_i^r may vary, in theory, between $-\infty$ and $+\infty$. In practice, however, accessibility has finite upper and lower limits. The upper limit is the system's attractiveness when delivery costs are zero throughout the system, while the lower limit is zero, since at least one destination in the system is attractive to exporters. In other words, the measured utility of exporting commodity r from origin i to at least one destination j in the set of feasible destinations is non-negative (i.e., $V_{ij}^r \geq 0$ for some $j \in D_i^r$); otherwise, commodity r will not be exported from origin i, and this origin should be removed from the analysis. Hence, it is assumed that accessibility is non-negative and can be specified as follows:

$$S_i^r = \max\{\ 0, \ln \sum_{j \in D_i^r} \exp\ (-\theta_i^r u_{ij}^r + A_j^r)\} \quad \text{for all origins} \tag{9}$$

4. *Trip generation*

It is assumed that the number of tons of commodity r exported from origin i is a function of the socio-economic activities at the origin, the socio-economic characteristics of the exporter, and transport system performance, expressed as follows:

$$\begin{aligned} G_i^r &= \alpha^r S_i^r + \sum_{l=1}^{L} \alpha_l^r q_l(E_{li}^r) \\ &= \alpha^r S_i^r + E_i^r \end{aligned} \quad \text{for all origins} \tag{10}$$

where

G_i^r = the number of tons of commodity r exported from origin i,

E_{li}^r = the value of the l^{th} socio-economic variable that influences the number of tons of commodity r exported from origin i,

$q_l(E_{li}^r)$ = a given function specifying how the l^{th} socio-economic variable, E_{li}^r, influences the number of tons of commodity r exported from origin i, and

E_i^r = a composite measure of the effect the socio-economic variables, which are exogenous to the transport system, have on the number of tons of commodity r exported from origin i.

The quantities α^r and α_l^r for $l = 1, 2, ..., L$ are coefficients to be estimated. Similar to A_j^r, E_i^r is assumed to be a fixed constant, and G_i^r depends solely on the system's performance as measured by the accessibility variable S_i^r. Therefore, in equation (10), G_i^r depends solely on the perceived delivery cost, u_{ij}^r, for all destinations that are feasible for importing commodity r exported from origin i, expressed as follows:

$$G_i^r = G_i^r(u_{ij}^r : j \in D_i^r) \tag{11}$$

5. *Trip distribution*

Based on the random utility theory of exporter behaviour (see the subsection on utility function above), it is assumed that the probability ($\Pr_{ij}^r$) that a typical exporter at any given origin i will choose to export commodity r to any given destination $j \in D_i^r$ is equal to the probability that the utility of exporting to destination j is equal to or greater than that of exporting to any other destination $k \in D_i^r$; that is,

$$\Pr_{ij}^r = \text{Probability}\left[v_{ij}^r \geq \forall k \in D_i^r\right] \tag{12}$$

Since it is assumed that the random (error) terms of the utility functions are independent and identically distributed as a type I extreme value probability distribution (Gumbel, 1985), equation (12) can be written as follows:

$$\Pr_{ij}^r = \frac{\exp(V_{ij}^r)}{\sum_{k \in D_i^r} \exp(V_{ik}^r)} \tag{13}$$

The number of tons of commodity r exported from origin i to destination j , T_{ij}^r , will therefore be a proportion of G_i^r based on $\Pr_{ij}^r$. T_{ij}^r may be expressed using the following logit model:

$$T_{ij}^r = G_i^r \frac{\exp(V_{ij}^r)}{\sum_{k \in D_i^r} \exp(V_{ik}^r)} \tag{14}$$

The above assumptions regarding exporter behaviour indicate that each importer will consider competitive alternative delivery costs for each commodity he wishes to import from different exporters at different origins.

If an importer at destination j knows the average selling price of commodity r , SP_j^r , and specifies a profit margin of MP_j^r , he will import commodity r from an exporter at origin i as long as

$$imc = SP_j^r - u_{ij}^r - MP_j^r \geq 0 \tag{15}$$

where imc is the import criterion.

Based on these assumptions, trip distribution can be expressed as follows:

$$T_{ij}^r = \left\{ \begin{array}{ll} G_i^r \dfrac{\exp(-\theta_i^r u_{ij}^r + A_j^r)}{\sum_{k \in D_i^r} \exp(-\theta_i^r u_{ik}^r + A_k^r)} & \text{if } imc \geq 0 \\ 0 & \text{otherwise} \end{array} \right\} \quad \text{for all O - D pairs} \tag{16}$$

Again, it may be seen that, for any origin i, T_{ij}^r depends solely on the perceived delivery cost, u_{ij}^r, for all import destinations that are feasible for the export of commodity r from origin i, as follows:

$$T_{ij}^r = T_{ij}^r(u_{ij}^r : j \in D_i^r) \tag{17}$$

Safwat and Magnanti (1988) showed that the combined trip-generation and trip-distribution model in STEM has an inverse whose matrix is symmetric and negative definite. This result is important for the formulation of IFSTEM and the computations involved.

6. *Link cost functions*

This study deals with two major types of links: the first comprises modal (real) links including road, rail, maritime and air links; the second comprises operational (dummy) links including export, import, transit-in, transit-out, pre-import, pre-export and transfer operation links. Each type is given its own cost function that depends upon the flow over the given link.

The modal link cost function can be expressed as follows:

$$C_a^r(F_a^r) = \gamma^r t_a^r(F_a^r) + TC_a^r(F_a^r) \quad \text{for all modal links } a \tag{18}$$

where

F_a^r = the flow, in tons, of commodity r on link a,

$C_a^r(F_a^r)$ = the generalized cost per unit of flow of commodity r on link a, using one of the feasible modes for F_a^r,

$t_a^r(F_a^r)$ = a function representing the delay per unit of flow of commodity r, on link a, using one of the feasible modes for F_a^r,

$TC_a^r(F_a^r)$ = a function representing the monetary cost per unit of flow of commodity r, on link a, using one of the feasible modes for F_a^r, and

γ^r = the value of the time as perceived by the exporters of commodity r.

The operational link cost function can be expressed as follows:

$$C_a^r(F_a^r) = \gamma^r \sum_k \text{tproc}_{ka}^r + \sum_k \text{cproc}_{ka}^r + \text{infc}(\text{nsig}, PC_i^r, F_a^r) + \text{tariffc}(PC_i^r, F_a^r) + \beta^r\ \text{EDIL}_a^r \tag{19}$$

where

tproc_{ka}^r = the time taken to finish administrative procedure k of operation a for commodity r,

cproc_{ka}^r = the administrative cost of procedure k of operation a for commodity r, infc = the informal cost as a function of the number of signatures, nsig; the unit price of commodity r at origin i, PC_i^r; and the flow F_a^r,

tariffc = the tariff cost of commodity r as a function of the unit price of commodity r at origin i, PC_i^r, and the flow F_a^r,

EDIL_a^r = the electronic data interchange (EDI) level of implementation used to perform operation a for commodity r; this level ranges from 0 to 5, with 0 representing full implementation of EDI and 5 representing no implementation of EDI, and

β^r = a parameter to be estimated that measures the cost of the limited implementation of EDI for the export of commodity r.

It is assumed that each link cost function depends on the flow over that link and should be continuous and non-decreasing.

All the functional forms and parameters of equations (18) and (19) need to be specified and calibrated for the real application of the model to ITSAM.

7. *Modal split and trip assignment*

Based on the network representation used in this study and practical considerations for freight transport, it is assumed that commodity r can be transferred from one mode to another as long as this transfer is feasible and reduces the total delivery cost (that is, the cost of transporting commodity from its origin i to destination j). Therefore, it is assumed that each exporter will choose the mode and route combination that minimizes the total cost of delivery to import destination node j from export origin node i.

The total perceived delivery cost for commodity r transported from export origin node i to import destination node j on any multimodal path p, C_p^r, is the sum of the perceived costs on the links comprising that multimodal path. This may be expressed as

$$C_p^r = \sum_{a \in A^r} \delta_{ap}^r C_a^r(F_a^r) \quad \text{for all paths} \tag{20}$$

where

$$\delta_{ap}^r = \begin{Bmatrix} 1 \text{ if link } a \text{ belongs to path } p \\ 0 \text{ otherwise} \end{Bmatrix} \text{for all paths}$$

These assumptions on modal split, trip assignment and system performance imply a Wardrop user equilibrium model of (multimodal) path choice. More precisely, if u_{ij}^r is identified as the minimum delivery cost, the perceived delivery costs on all used multimodal paths for any given O-D pair are equal to or less than those on unused multimodal paths, which may be expressed as follows:

$$C_p^r \begin{Bmatrix} = u_{ij}^r & \text{if } H_p^r > 0 \\ \geq u_{ij}^r & \text{if } \mathrm{H}_\mathrm{p}^\mathrm{r} = 0 \end{Bmatrix} \quad \text{for all paths} \tag{21}$$

where H_p^r is the flow of commodity r on multimodal path p and the link-path incidence relationships are as follows:

$$F_a^r = \sum_{p \in P^r} \delta_{ap}^r H_p^r \qquad \text{for all links} \qquad (22)$$

This relationship indicates that the flow of commodity r on a given link a equals the sum of all flows of that commodity on all paths sharing that link.

This specification is based on the assumption that the demand for the transport of one commodity is independent of that of another. In other words, the movement of different commodities is assumed to involve independent interaction with the transportation system. For this reason, they can be modelled separately, and IFSTEM may therefore be decomposed by commodity type. Additionally, since capacity issues are generally not a principle concern in regional or international freight transportation planning, it is not necessary to simultaneously assign multi-commodity flows to this international network; a simplified separation of freight into commodity groupings is sufficiently relevant. Each commodity or sector becomes a layer, and together all relevant layers provide an aggregate estimate of all freight traffic volumes at a level of accuracy that is useful for planning.

The model decision variables for commodity r are S_i^r, T_{ij}^r and H_p^r, which are interrelated through the minimum delivery cost u_{ij}^r (see equations 8, 17 and 21). These interrelationships allow a simultaneous prediction of trip generation, trip distribution, modal choice and trip assignment that is internally consistent and is superior to the sequential approach that has been used worldwide for more than four decades (see Safwat, 1982; Safwat and Magnanti, 1988; Hasan and Safwat, 2000; Hasan and Al-Gadhi, 1998).

III. APPLICATION TO A PROTOTYPE

It was considered advisable to test IFSTEM on a prototype before applying the model to ITSAM. A summarized account of this exercise, provided below, demonstrates the application process in terms of input requirements and output results and also explains in some detail the network representation and its associated input files.

A. PROTOTYPE NETWORK REPRESENTATION

In the prototype only six ESCWA member countries are considered: Iraq, Jordan, Kuwait, Lebanon, Saudi Arabia and the Syrian Arab Republic. The real international road, rail, air and maritime networks are simplified, as shown in annex figures X-XIII respectively, with the zonal system consisting of the capitals of these countries in addition to Jeddah and Dammam in Saudi Arabia. Different types of commodities, measured in tons, may be imported or exported to or from each zone (only one commodity type is considered in the prototype).

Annex figures X and XI show the prototype road and railway networks. It is assumed that both networks serve exactly the same set of locations and that the possibility exists for transfer between road and rail modes at each location. For those two modes the ALO at each land border point follows the pattern represented in annex figure IX; in the figure, node 102 of the road network represents the Khafji border point in Saudi Arabia and node 200 represents the Nuwayseeb border point in Kuwait. The determination of ALO type (export, import, transit-in or transit-out) at each border point depends on the O-D pair, as previously mentioned. In the prototype four O-D pairs are considered, as shown in annex table 1. It is also assumed that a commodity can be transported using any one or a combination of four transport modes (road, rail, air and/or sea). The origin and destination in any O-D pair shown in annex table 1 is considered the O-D pair super origin and super destination, as shown in annex figure IX.

Annex figure XII shows the airline network that connects the six capital cities and Dammam and Jeddah. The maritime network, which is shown in annex figure XIII, includes only four seaports: Beirut, Dammam, Jeddah and Kuwait.

B. COMPUTER PROGRAM CODE

A computer program code for STEM was developed earlier by Safwat (1982) and Safwat and Walton (1988). Hasan (1991), Hasan and Al-Ghadi (1998), and Hasan and Safwat (2000) enhanced the STEM code through applications of the model to the urban passenger transport networks of Riyadh, Saudi Arabia, and Tyler, Texas. The STEM computer program code has been maintained by the REDI Foundation in College Station, Texas, since 1992 (see Hasan and Safwat, 1992-2000) and was made available to the Transport Section at ESCWA for its adaptation to IFSTEM.

C. INPUT FILES

In implementing the network representations for IFSTEM requirements, the following input files were utilized:

(a) Link performance files;
(b) Zonal files for socio-economic variables and parameters;
(c) O-D commodity files.

Link performance files are those that are related or have contributed to the performance side of IFSTEM. They include the following:

(a) Modal link files:

(i) Road link file;

(ii) Rail link file;
(iii) Air link file;
(iv) Maritime (sea) link file;

(b) Border/ports/zone operational link files:

(i) Export link file;
(ii) Import link file;
(iii) Transit-in link file;
(iv) Transit-out link file;
(v) Pre-export link file;
(vi) Pre-import link file;
(vii) Transfer link file.

Each performance link file consists of a link identification number (LIN) and other numbers representing origin and destination nodes (from node [FN] and to node [TN]), link type (LT), and several link characteristic variables (LCVs) for each item listed. The file is set up as follows:

LIN	FN	TN	LT	LCV1	LCV2	....	LCVn

Link characteristic variables are used in the calculation of link cost functions, which should be calibrated using observed data for these variables. In this prototype a fictitious link cost function is used for each link type, and no LCVs are included. In the real application of IFSTEM to ITSAM, the calibration process for these cost functions will be shown. The link types are classified as follows: road = 1; rail = 2; air = 3; maritime = 4; transfer = 10; export = 11; import = 12; transit-in = 13; transit-out = 14; pre-export = 16; pre-import = 17; and dummy = 18. The files belonging to this first category (link performance) are shown in annex tables 2 to 13.

The second and third groups of files are related to the demand side of IFSTEM.

In the prototype, three production socio-economic variables of E^r_{li} and three attraction socio-economic variables of A^r_{wj} are considered and the forecast values of these variables are assumed, as shown in the zonal file for the socio-economic variables, represented in annex table 14. This file includes only those zones represented by the four O-D pair commodity files shown in annex table 1. In addition, values are assumed for the parameters $\hat{\alpha}^r$, $\hat{\alpha}^r_l$, $\hat{\theta}^r_l$, and $\hat{\theta}^r_{lw}$, as shown in annex tables 15 and 16.

The third group of files comprises the O-D commodity files, including one for each commodity type. These files contain information about the commodity type, the O-D pairs associated with a given commodity, the mode or combination of modes the commodity can use, and the observed traffic volume (in tons) for each O-D pair used for the given commodity.

In the prototype only one commodity type is considered, and it is assumed that this commodity can be transported by one or a combination of the four modes.

D. Link cost functions

The supply side of IFSTEM is represented by a set of link cost functions for different modes and operations. In the prototype, the following link cost functions are assumed:

(a) Modal link cost function for road, rail, air and maritime transport:

$$C_a(F_a) = b + cF_a + dF_a^2 + eDist_a \qquad (23)$$

where b, c, d and e are constants whose values depend on the mode type; F_a is the link flow; and $Dist_a$ is the link length in kilometres (km). The assumed values of these constants are given in annex table 17;

(b) Operational link cost function for export, import, transit-in, transit-out, pre-export, pre-import and transfer procedures:

$$C_a(F_a) = n + mF_a \qquad (24)$$

where n and m are constants whose values depend on the type of operation. The assumed values are given in annex table 17.

E. OUTPUT RESULTS

The authors of the present study, using the network representation and input files described above, ran the computer program devised for IFSTEM through five iterations. The output results comprising the final solution for one commodity are presented in annex tables 18-27 and annex figures XIV-XVIII.

Annex table 18 and annex figure XIV show that the first O-D pair, Jeddah-Baghdad, has only one path: Jeddah $\underset{\text{rail}}{\rightarrow}$ Jdeydet Ar'ar (Saudi Arabian border) $\underset{\text{rail}}{\rightarrow}$ Jdeydet Ar'ar (Iraqi border) $\underset{\text{rail}}{\rightarrow}$ Baghdad, with a total flow of 128.29 tons and a total cost of 487.75 cost units. This is the most travelled path for the given O-D pair. The rail mode is used all along this path, as it is cheaper than road transport.

Annex table 19 and annex figure XV show that there are two competitive paths between Riyadh and Beirut with almost the same total cost. This reflects the equilibrium concept for exporters defined earlier. The options include:

(a) Path 1: Riyadh $\underset{\text{rail}}{\rightarrow}$ Jeddah $\underset{\text{maritime}}{\rightarrow}$ Beirut;

(b) Path 2: Riyadh $\underset{\text{rail}}{\rightarrow}$ Hadithah $\underset{\text{rail}}{\rightarrow}$ Omari $\underset{\text{rail}}{\rightarrow}$ Amman $\underset{\text{rail}}{\rightarrow}$ Jaber $\underset{\text{rail}}{\rightarrow}$ Nasib $\underset{\text{rail}}{\rightarrow}$ Damascus $\underset{\text{rail}}{\rightarrow}$ Jdeydet Yabus $\underset{\text{rail}}{\rightarrow}$ Masna $\underset{\text{rail}}{\rightarrow}$ Beirut.

The combination of rail and maritime modes makes path 1 competitive with (and even slightly cheaper than) the longer rail-based path 2. The first option reflects the multimodal concept (the possibility of transferring a commodity from one mode to another during a journey from an origin to a destination) highlighted in the present study. The flow on path 1 was 119.4 tons and the total cost was 646.2 cost units; the corresponding figures for path 2 were 79.6 tons and 651.1 cost units. The results suggest that path 1 is likely to be used more than path 2 because of its lower total cost. It should be noted, however, that in the representation of the cost of the maritime link between Jeddah to Beirut, the cost of passing through the Suez Canal was not factored in; in the real application of the model this would have to be incorporated.

Annex table 20 and annex figure XVI show that the O-D pair Damascus-Kuwait has one path with a total flow of 127.7 tons and a total cost of 560.8 cost units. This path includes the following links: Damascus $\underset{\text{rail}}{\rightarrow}$ Tanf $\underset{\text{rail}}{\rightarrow}$ Al-Walid $\underset{\text{rail}}{\rightarrow}$ Baghdad $\underset{\text{rail}}{\rightarrow}$ Safwan $\underset{\text{rail}}{\rightarrow}$ Abdali $\underset{\text{rail}}{\rightarrow}$ Kuwait. For this O-D pair the path delineated provides the best option.

Annex table 21 and annex figure XVII show that there are two competitive paths for the O-D pair Damascus-Jeddah. Path 1 has a total flow of 141.5 tons and a total cost of 593.7 cost units and consists of the following links: Damascus $\underset{\text{rail}}{\rightarrow}$ Nasib $\underset{\text{rail}}{\rightarrow}$ Jaber $\underset{\text{rail}}{\rightarrow}$ Amman $\underset{\text{rail}}{\rightarrow}$ Al-Mudawwarah $\underset{\text{rail}}{\rightarrow}$ Halat Ammar $\underset{\text{rail}}{\rightarrow}$ Jeddah. Path 2 has a total flow of 75.4 tons and a total cost of 601.6 cost units and consists of the following links: Damascus $\underset{\text{rail}}{\rightarrow}$ Jdeydet Yabus $\underset{\text{rail}}{\rightarrow}$ Masna $\underset{\text{rail}}{\rightarrow}$ Beirut $\underset{\text{maritime}}{\rightarrow}$ Jeddah. The analysis of the results for this O-D pair is similar to that for Riyadh-Beirut.

The various types of ALOs performed along each path are also shown in annex tables 18-21. The commodity starts from a dummy origin (the super origin shown in annex figure VIII), which may be a warehouse; it is then loaded onto a truck on the nearest road, and the exporter prepares the pre-export ALO (if necessary). The commodity may be transported by road until it reaches its destination; however, it may be transferred to a lower-cost mode (rail, for example) if that option exists, as is demonstrated in the results shown in annex tables 18-21.

The six paths used for the assignment of traffic on the multimodal prototype network are shown in annex figure XVIII, and relevant details for each link (such as flow and cost) are provided in annex table 22. The table and figure make up what is called the flow pattern, which can be used in the impact analysis for a given set of alternatives and considered inputs for the impact models.

Annex table 23 summarizes the six path flows for the four O-D pairs (for one type of commodity), showing a total commodity flow of 671.9 tons. Annex table 24 aggregates the path flows into trip distribution flows covering six zones: Baghdad, Beirut, Damascus, Jeddah, Kuwait and Riyadh. Annex table 25 shows the path unit costs, and annex table 26 combines the results of annex tables 23 and 25 to calculate path total costs, which are aggregated in annex table 27 to represent total trip distribution costs. The combined results indicate that in the prototype 671.88 tons of one type of commodity are transported between four O-D pairs at a total cost of 392,546.45 cost units—an average of 584.3 cost units/ton. In a real-world application of IFSTEM, the information produced by the model would be extremely useful for issue analysis and policy formulation.

IV. CONCLUSIONS AND FUTURE ACTIVITIES

A. CONCLUSIONS

The authors of this study have developed an international freight simultaneous transportation equilibrium model (IFSTEM) to predict equilibrium flow patterns that can describe the behaviour of exporters and importers of different commodities over an international multimodal network covering ESCWA member countries. The model simultaneously predicts trip generation, trip distribution, modal split and trip assignment and is essentially based on STEM, a model developed by Safwat (1982) and Safwat and Magnanti (1988). IFSTEM is considered a central component of the ITSAM-FRAMEWORK, which is one of the three major elements of the Integrated Transport System in the Arab Mashreq. The network representation associated with IFSTEM exemplifies the multimodal concept, whereby a commodity can be transferred from one mode to another during its journey from its origin to its destination.

Administrative and logistical operations are mathematically represented by links that are considered integral components of any multimodal path. The delivery cost from an origin to a destination using any multimodal path will be influenced by the ALO costs all along that path. Therefore, the model can test different policy scenarios that take into account the variables affecting ALO cost. The main objective of IFSTEM is to show how the increase in trade between ESCWA member countries that would result from supply-related improvements in the region's transport system could be measured. Such improvements would involve the establishment of a better transportation infrastructure, increased transportation network integration (based on the multimodal concept), and the facilitation of border procedures and regulations (ALOs) in terms of cost and time. IFSTEM is capable of measuring the effects of these supply improvements when applied to real world situations. The model can also be used to measure changes in demand (through an assessment of changes in socio-economic variables) and to predict how such changes will affect the supply side.

The prototype results show that the model satisfies the behavioural aspects of the application and its solution procedure is computationally tractable. This should encourage the full implementation of IFSTEM as a policy analysis tool and a decision-support system for transport policy makers in the region.

B. FUTURE ACTIVITIES

The development of IFSTEM, its solution procedure, and its application to a prototype network is believed to constitute a major step towards the ultimate objective of the full implementation of the model for the real multimodal network in the ESCWA region. Full implementation would include, but would not be limited to, the following activities:

(a) The design and implementation of a calibration process for the IFSTEM demand models (the calibration of trip generation and trip distribution models to estimate the model parameters);

(b) The design and implementation of a calibration process for the IFSTEM performance models (the calibration of link performance functions for different mode and operation types);

(c) The validation of the models' capability to reproduce base-year inputs;

(d) The validation of models' predictive power to forecast future flows;

(e) The development of simulation models for ALO operations at land border points, seaports and airports, and their integration within IFSTEM;

(f) The geographic integration of IFSTEM with its database;

(g) The development of a user-friendly interface to perform graphic policy scenario analyses on ITSAM using IFSTEM.

Proper data collection and management is essential for the implementation of most of these steps; thus, parallel efforts are needed to develop ITSAM-INFOSYS.

ANNEX TABLES

ANNEX TABLE 1. COMMODITY ORIGIN-DESTINATION PAIRS

O-D pair No.	Origin	Destination
1	15 416 (Jeddah)	35 317 (Baghdad)
2	15 016 (Riyadh)	65 117 (Beirut)
3	45 116 (Damascus)	25 117 (Kuwait)
4	45 116 (Damascus)	15 417 (Jeddah)

ANNEX TABLE 2. ROAD LINK FILE

Link identification No.	From node	To node	Link type	Distance (km)	Link identification No.	From node	To node	Link type	Distance (km)
1	100	101	1	389	55	20 213	201	1	120
2	100	104	1	958	56	30 113	303	1	528
3	104	100	1	958	57	10 311	304	1	10
4	10 512	104	1	1 200	58	10 314	304	1	10
5	101	100	1	389	59	30 411	103	1	10
6	104	105	1	1 200	60	30 414	103	1	10
7	101	103	1	1 108	61	10 511	501	1	10
8	10 312	101	1	1 108	62	10 514	501	1	10
9	10 212	101	1	298	63	50 111	105	1	10
10	101	102	1	298	64	50 114	105	1	10
11	20 012	201	1	108	65	20 211	301	1	10
12	20 212	201	1	120	66	20 214	301	1	10
13	201	200	1	108	67	30 111	202	1	10
14	201	202	1	120	68	30 114	202	1	10
15	303	304	1	432	69	40 011	305	1	10
16	303	301	1	528	70	40 014	305	1	10
17	30 612	303	1	512	71	30 511	400	1	10
18	303	306	1	512	72	30 514	400	1	10
19	30 512	303	1	350	73	50 011	306	1	10
20	30 112	303	1	528	74	50 014	306	1	10
21	303	305	1	350	75	30 611	500	1	10
22	502	500	1	445	76	30 614	500	1	10
23	50 312	502	1	114	77	50 311	402	1	10
24	50 112	502	1	330	78	50 314	402	1	10
25	50 012	502	1	445	79	40 211	503	1	10
26	502	503	1	114	80	40 214	503	1	10
27	502	501	1	330	81	40 311	600	1	10
28	401	400	1	675	82	40 314	600	1	10
29	401	403	1	52	83	60 011	403	1	10
30	40 212	401	1	104	84	60 014	403	1	10
31	40 012	401	1	675	85	100	103	1	1 108
32	401	402	1	104	86	100	105	1	1 400
33	403	401	1	52	87	100	106	1	1 477
34	601	600	1	72	88	101	106	1	1 583
35	60 012	601	1	72	89	104	103	1	1 558
36	10 213	101	1	298	90	104	106	1	1 609
37	20 013	201	1	108	91	10 312	100	1	1 108
38	10 211	200	1	10	92	10 312	104	1	1 558
39	10 214	200	1	10	93	10 313	100	1	1 108
40	20 011	102	1	10	94	10 313	104	1	1 558
41	20 014	102	1	10	95	10 512	100	1	1 400
42	10 313	101	1	1 108	96	10 513	100	1	1 400
43	10 513	104	1	1 200	97	10 612	100	1	1 477
44	30 412	303	1	432	98	10 612	101	1	1 583
45	30 413	303	1	432	99	10 612	104	1	1 609
46	30 613	303	1	512	100	10 613	100	1	1 477
47	30 513	303	1	350	101	10 613	101	1	1 583
48	50 013	502	1	445	102	10 613	104	1	1 609
49	50 113	502	1	330	103	10 611	504	1	10
50	50 313	502	1	114	104	10 614	504	1	10
51	40 013	401	1	675	105	50 412	502	1	175
52	40 213	401	1	104	106	50 413	502	1	175
53	40 313	401	1	52	107	50 411	106	1	10
54	60 013	601	1	72	108	50 414	106	1	10

ANNEX TABLE 3. RAIL LINK FILE

Link identification No.	From node	To node	Link type	Distance (km)	Link identification No.	From node	To node	Link type	Distance (km)
1	110	111	2	389	55	21 213	211	2	120
2	110	114	2	958	56	31 113	313	2	528
3	114	110	2	958	57	11 311	314	2	10
4	11 512	114	2	1 200	58	11 314	314	2	10
5	111	110	2	389	59	31 411	113	2	10
6	114	115	2	1 200	60	31 414	113	2	10
7	111	113	2	1 108	61	11 511	511	2	10
8	11 312	111	2	1 108	62	11 514	511	2	10
9	11 212	111	2	298	63	51 111	115	2	10
10	111	112	2	298	64	51 114	115	2	10
11	21 012	211	2	108	65	21 211	311	2	10
12	21 212	211	2	120	66	21 214	311	2	10
13	211	210	2	108	67	31111	212	2	10
14	211	212	2	120	68	31 114	212	2	10
15	313	314	2	432	69	41 011	315	2	10
16	313	311	2	528	70	41 014	315	2	10
17	31 612	313	2	512	71	31 511	410	2	10
18	313	316	2	512	72	31 514	410	2	10
19	31 512	313	2	350	73	51 011	316	2	10
20	31 112	313	2	528	74	51 014	316	2	10
21	313	315	2	350	75	31 611	510	2	10
22	512	510	2	445	76	31 614	510	2	10
23	51 312	512	2	114	77	51 311	412	2	10
24	51 112	512	2	330	78	51 314	412	2	10
25	51 012	512	2	445	79	41 211	513	2	10
26	512	513	2	114	80	41 214	513	2	10
27	512	511	2	330	81	41 311	610	2	10
28	411	410	2	675	82	41 314	610	2	10
29	411	413	2	52	83	61 011	413	2	10
30	41 212	411	2	104	84	61 014	413	2	10
31	41 012	411	2	675	85	110	113	2	1 108
32	411	412	2	104	86	110	115	2	1 400
33	413	411	2	52	87	110	116	2	1 477
34	611	610	2	72	88	111	116	2	1 583
35	61 012	611	2	72	89	114	113	2	1 558
36	11 213	111	2	298	90	114	116	2	1 609
37	21 013	211	2	108	91	11 312	110	2	1 108
38	11 211	210	2	10	92	11 312	114	2	1 558
39	11 214	210	2	10	93	11 313	110	2	1 108
40	21 011	112	2	10	94	11 313	114	2	1 558
41	21 014	112	2	10	95	11 512	110	2	1 400
42	11 313	111	2	1 108	96	11 513	110	2	1 400
43	11 513	114	2	1 200	97	11 612	110	2	1 477
44	31 412	313	2	432	98	11 612	111	2	1 583
45	31 413	313	2	432	99	11 612	114	2	1 609
46	31 613	313	2	512	100	11 613	110	2	1 477
47	31 513	313	2	350	101	11 613	111	2	1 583
48	51 013	512	2	445	102	11 613	114	2	1 609
49	51 113	512	2	330	103	11 611	514	2	10
50	51 313	512	2	114	104	11 614	514	2	10
51	41 013	411	2	675	105	51 412	512	2	175
52	41 213	411	2	104	106	51 413	512	2	175
53	41 313	411	2	52	107	51 411	116	2	10
54	61 013	611	2	72	108	51 414	116	2	10

ANNEX TABLE 4. AIRLINE LINK FILE

Link identification No.	From node	To node	Link type	Distance (km)	Link identification No.	From node	To node	Link type	Distance (km)
1	12 411	120	3	980	57	32 311	124	3	1 610
2	12 411	121	3	1 470	58	32 311	120	3	1 120
3	12 411	221	3	1 470	59	32 311	121	3	1 120
4	12 411	323	3	1 610	60	32 311	221	3	630
5	12 411	522	3	1 330	61	32 311	522	3	1 050
6	12 411	421	3	1 540	62	32 311	421	3	980
7	12 411	621	3	1 610	63	32 311	621	3	1 120
8	12 414	120	3	980	64	32 314	124	3	1 610
9	12 414	121	3	1 470	65	32 314	120	3	1 120
10	12 414	221	3	1 470	66	32 314	121	3	1 120
11	12 414	323	3	1 610	67	32 314	221	3	630
12	12 414	522	3	1 330	68	32 314	522	3	1 050
13	12 414	421	3	1 540	69	32 314	421	3	980
14	12 414	621	3	1 610	70	32 314	621	3	1 120
15	12 011	124	3	980	71	52 211	124	3	1 330
16	12 011	121	3	490	72	52 211	120	3	1 610
17	12 011	221	3	630	73	52 211	121	3	1 890
18	12 011	323	3	1 120	74	52 211	221	3	1 540
19	12 011	522	3	1 610	75	52 211	323	3	1 050
20	12 011	421	3	1 680	76	52 211	421	3	210
21	12 011	621	3	1 750	77	52 211	621	3	280
22	12 014	124	3	980	78	52 214	124	3	1 330
23	12 014	121	3	490	79	52 214	120	3	1 610
24	12 014	221	3	630	80	52 214	121	3	1 890
25	12 014	323	3	1 120	81	52 214	221	3	1 540
26	12 014	522	3	1 610	82	52 214	323	3	1 050
27	12 014	421	3	1 680	83	52 214	421	3	210
28	12 014	621	3	1 750	84	52 214	621	3	280
29	12 111	124	3	1 470	85	42 111	124	3	1 540
30	12 111	120	3	490	86	42 111	120	3	1 680
31	12 111	221	3	490	87	42 111	121	3	1 890
32	12 111	323	3	1 120	88	42 111	221	3	1 540
33	12 111	522	3	1 890	89	42 111	323	3	980
34	12 111	421	3	1 890	90	42 111	522	3	210
35	12 111	621	3	2 030	91	42 111	621	3	140
36	12 114	124	3	1 470	92	42 114	124	3	1 540
37	12 114	120	3	490	93	42 114	120	3	1 680
38	12 114	221	3	490	94	42 114	121	3	1 890
39	12 114	323	3	1 120	95	42 114	221	3	1 540
40	12 114	522	3	1 890	96	42 114	323	3	980
41	12 114	421	3	1 890	97	42 114	522	3	210
42	12 114	621	3	2 030	98	42 114	621	3	140
43	22 111	124	3	1 470	99	62 111	124	3	1 610
44	22 111	120	3	630	100	62 111	120	3	1 750
45	22 111	121	3	490	101	62 111	121	3	2 030
46	22 111	323	3	630	102	62 111	221	3	1 610
47	22 111	522	3	1 540	103	62 111	323	3	1 120
48	22 111	421	3	1 540	104	62 111	522	3	280
49	22 111	621	3	1 610	105	62 111	421	3	140
50	22 114	124	3	1 470	106	62 114	124	3	1 610
51	22 114	120	3	630	107	62 114	120	3	1 750
52	22 114	121	3	490	108	62 114	121	3	2 030
53	22 114	323	3	630	109	62 114	221	3	1 610
54	22 114	522	3	1 540	110	62 114	323	3	1 120
55	22 114	421	3	1 540	111	62 114	522	3	280
56	22 114	621	3	1 610	112	62 114	421	3	140

ANNEX TABLE 5. MARITIME LINK FILE

Link identification No.	From node	To node	Link type	Distance (km)
1	13 411	131	4	4 550
2	13 411	631	4	2 100
3	13 414	131	4	4 550
4	13 414	631	4	2 100
5	13 111	231	4	490
6	13 111	134	4	4 550
7	13 114	231	4	490
8	13 114	134	4	4 550
9	23 111	131	4	490
10	23 114	131	4	490
11	63 111	134	4	2 100
12	63 114	134	4	2 100

ANNEX TABLE 6. PRE-EXPORT LINK FILE

Link identification No.	From node	To node	Link type
1	10 416	104	16
2	10 016	100	16
3	40 116	401	16
4	11 416	114	16
5	11 016	110	16
6	41 116	411	16
7	12 416	124	16
8	12 016	120	16
9	42 116	421	16
10	13 416	134	16

ANNEX TABLE 7. PRE-IMPORT LINK FILE

Link identification No.	From node	To node	Link type
1	303	30 317	17
2	601	60 117	17
3	201	20 117	17
4	104	10 417	17
5	313	31 317	17
6	611	61 117	17
7	211	21 117	17
8	114	11 417	17
9	323	32 317	17
10	621	62 117	17
11	221	22 117	17
12	124	12 417	17
13	134	13 417	17
14	631	63 117	17
15	231	23 117	17

ANNEX TABLE 8. EXPORT LINK FILE

Link identification No.	From node	To node	Link type
1	102	10 211	11
2	200	20 011	11
3	103	10 311	11
4	304	30 411	11
5	105	10 511	11
6	501	50 111	11
7	306	30 611	11
8	500	50 011	11
9	503	50 311	11
10	402	40 211	11
11	305	30 511	11
12	400	40 011	11
13	403	40 311	11
14	600	60 011	11
15	202	20 211	11
16	301	30 111	11
17	112	11 211	11
18	210	21 011	11
19	113	11 311	11
20	314	31 411	11
21	115	11 511	11
22	511	51 111	11
23	316	31 611	11
24	510	51 011	11
25	513	51 311	11
26	412	41 211	11
27	315	31 511	11
28	410	41 011	11
29	413	41 311	11
30	610	61 011	11
31	212	21 211	11
32	311	31 111	11
33	124	12 411	11
34	120	12 011	11
35	121	12 111	11
36	221	22 111	11
37	323	32 311	11
38	522	52 211	11
39	421	42 111	11
40	621	62 111	11
41	134	13 411	11
42	131	13 111	11
43	231	23 111	11
44	631	63 111	11
45	106	10 611	11
46	116	11 611	11
47	504	50 411	11
48	514	51 411	11

ANNEX TABLE 9. IMPORT LINK FILE

Link identification No.	From node	To node	Link type
1	102	10 212	12
2	200	20 012	12
3	103	10 312	12
4	304	30 412	12
5	105	10 512	12
6	501	50 112	12
7	306	30 612	12
8	500	50 012	12
9	503	50 312	12
10	402	40 212	12
11	305	30 512	12
12	400	40 012	12
13	403	40 312	12
14	600	60 012	12
15	202	20 212	12
16	301	30 112	12
17	112	11 212	12
18	210	21 012	12
19	113	11 312	12
20	314	31 412	12
21	115	11 512	12
22	511	51 112	12
23	316	31 612	12
24	510	51 012	12
25	513	51 312	12
26	412	41 212	12
27	315	31 512	12
28	410	41 012	12
29	413	41 312	12
30	610	61 012	12
31	212	21 212	12
32	311	31 112	12
33	124	12 412	12
34	120	12 012	12
35	121	12 112	12
36	221	22 112	12
37	323	32 312	12
38	522	52 212	12
39	421	42 112	12
40	621	62 112	12
41	134	13 412	12
42	131	13 112	12
43	231	23 112	12
44	631	63 112	12
45	106	10 612	12
46	116	11 612	12
47	504	50 412	12
48	514	51 412	12

ANNEX TABLE 10. TRANSIT-IN LINK FILE

Link identification No.	From node	To node	Link type
1	102	10 213	13
2	200	20 013	13
3	103	10 313	13
4	304	30 413	13
5	105	10 513	13
6	501	50 113	13
7	306	30 613	13
8	500	50 013	13
9	503	50 313	13
10	402	40 213	13
11	305	30 513	13
12	400	40 013	13
13	403	40 313	13
14	600	60 013	13
15	202	20 213	13
16	301	30 113	13
17	112	11 213	13
18	210	21 013	13
19	113	11 313	13
20	314	31 413	13
21	115	11 513	13
22	511	51 113	13
23	316	31 613	13
24	510	51 013	13
25	513	51 313	13
26	412	41 213	13
27	315	31 513	13
28	410	41 013	13
29	413	41 313	13
30	610	61 013	13
31	212	21 213	13
32	311	31 113	13
33	124	12 413	13
34	120	12 013	13
35	121	12 113	13
36	221	22 113	13
37	323	32 313	13
38	522	52 213	13
39	421	42 113	13
40	621	62 113	13
41	134	13 413	13
42	131	13 113	13
43	231	23 113	13
44	631	63 113	13
45	106	10 613	13
46	116	11 613	13
47	504	50 413	13
48	514	51 413	13

ANNEX TABLE 11. TRANSIT-OUT LINK FILE

Link identification No.	From node	To node	Link type
1	102	10 214	14
2	200	20 014	14
3	103	10 314	14
4	304	30 414	14
5	105	10 514	14
6	501	50 114	14
7	306	30 614	14
8	500	50 014	14
9	503	50 314	14
10	402	40 214	14
11	305	30 514	14
12	400	40 014	14
13	403	40 314	14
14	600	60 014	14
15	202	20 214	14
16	301	30 114	14
17	112	11 214	14
18	210	21 014	14
19	113	11 314	14
20	314	31 414	14
21	115	11 514	14
22	511	51 114	14
23	316	31 614	14
24	510	51 014	14
25	513	51 314	14
26	412	41 214	14
27	315	31 514	14
28	410	41 014	14
29	413	41 314	14
30	610	61 014	14
31	212	21 214	14
32	311	31 114	14
33	124	12 414	14
34	120	12 014	14
35	121	12 114	14
36	221	22 114	14
37	323	32 314	14
38	522	52 214	14
39	421	42 114	14
40	621	62 114	14
41	134	13 414	14
42	131	13 114	14
43	231	23 114	14
44	631	63 114	14
45	106	10 614	14
46	116	11 614	14
47	504	50 414	14
48	514	51 414	14

ANNEX TABLE 12. TRANSFER LINK FILE

Link identification No.	From node	To node	Link type
1	104	114	10
2	104	124	10
3	104	134	10
4	100	110	10
5	100	120	10
6	101	111	10
7	101	121	10
8	101	131	10
9	201	211	10
10	201	221	10
11	201	231	10
12	303	313	10
13	303	323	10
14	502	512	10
15	502	522	10
16	401	411	10
17	401	421	10
18	601	611	10
19	601	621	10
20	601	631	10
21	114	104	10
22	114	124	10
23	114	134	10
24	110	100	10
25	110	120	10
26	111	101	10
27	111	121	10
28	111	131	10
29	211	201	10
30	211	221	10
31	211	231	10
32	313	303	10
33	313	323	10
34	512	502	10
35	512	522	10
36	411	401	10
37	411	421	10
38	611	601	10
39	611	621	10
40	611	631	10
41	12 412	104	10
42	12 412	114	10
43	12 412	134	10
44	12 413	104	10
45	12 413	114	10
46	12 413	134	10
47	12 012	100	10
48	12 012	110	10
49	12 013	100	10
50	12 013	110	10
51	12 112	101	10
52	12 112	111	10
53	12 112	131	10
54	12 113	101	10
55	12 113	111	10
56	12 113	131	10
57	22 112	201	10
58	22 112	211	10
59	22 112	231	10
60	22 113	201	10
61	22 113	211	10
62	22 113	231	10
63	32 312	303	10
64	32 312	313	10
65	32 313	303	10
66	32 313	313	10
67	52 212	502	10
68	52 212	512	10
69	52 213	502	10
70	52 213	512	10
71	42 112	401	10
72	42 112	411	10
73	42 113	401	10
74	42 113	411	10
75	62 112	601	10
76	62 112	611	10
77	62 112	631	10
78	62 113	601	10
79	62 113	611	10
80	62 113	631	10
81	13 412	104	10
82	13 412	114	10
83	13 412	124	10
84	13 413	104	10
85	13 413	114	10
86	13 413	124	10
87	13 112	101	10
88	13 112	111	10
89	13 112	121	10
90	13 113	101	10
91	13 113	111	10
92	13 113	121	10
93	23 112	201	10
94	23 112	211	10
95	23 112	221	10
96	23 113	201	10
97	23 113	211	10
98	23 113	221	10
99	63 112	601	10
100	63 112	611	10
101	63 112	621	10
102	63 113	601	10
103	63 113	611	10
104	63 113	621	10
105	106	116	10
106	116	106	10
107	504	514	10
108	514	504	10

ANNEX TABLE 13. DUMMY LINK FILE

Link identification No.	From node	To node	Link type
1	15 416	10 416	18
2	15 416	11 416	18
3	15 416	12 416	18
4	15 416	13 416	18
5	15 016	10 016	18
6	15 016	11 016	18
7	15 016	12 016	18
8	45 116	40 116	18
9	45 116	41 116	18
10	45 116	42 116	18
11	30 317	35 317	18
12	31 317	35 317	18
13	32 317	35 317	18
14	60 117	65 117	18
15	61 117	65 117	18
16	62 117	65 117	18
17	63 117	65 117	18
18	20 117	25 117	18
19	21 117	25 117	18
20	22 117	25 117	18
21	23 117	25 117	18
22	10 417	15 417	18
23	11 417	15 417	18
24	12 417	15 417	18
25	13 417	15 417	18

ANNEX TABLE 14. ZONAL FILE FOR SOCIO-ECONOMIC VARIABLES

Zone node No.	Production socio-economic variable 1	Production socio-economic variable 2	Production socio-economic variable 3	Attraction socio-economic variable 1	Attraction socio-economic variable 2	Attraction socio-economic variable 3
15 416	1 000	3 000	2 000	2 000	2 000	400
15 016	2 000	5 000	3 000	3 000	3 000	600
45 116	5 000	9 000	5 000	6 000	9 000	500
35 317	4 000	1 000	6 000	5 000	8 000	800
65 117	6 000	2 000	2 000	9 000	6 000	900
25 117	7 000	3 000	5 000	8 000	4 000	700
15 417	3 000	4 000	6 000	7 000	8 000	600

ANNEX TABLE 15. ZONAL PARAMETER FILE FOR ALPHA

α	α_1	α_2	α_3
500	0.21	0.47	2.5

ANNEX TABLE 16. ZONAL PARAMETER FILE FOR THETA

Zone node No.	θ_i	θ_{i1}	θ_{i2}	θ_{i3}
15 416	0.05	0.0001	0.0003	0.0001
15 016	0.05	0.0002	0.0004	0.0002
45 116	0.05	0.00025	0.0006	0.0004
35 317	0.09	0.0007	0.0009	0.0005
65 117	0.08	0.0009	0.0006	0.0001
25 117	0.01	0.0001	0.0004	0.0006
15 417	0.04	0.0002	0.0002	0.0007

ANNEX TABLE 17. PARAMETER FILE FOR LINK COST FUNCTIONS

	Parameters					
Mode/operation	*b*	*c*	*d*	*e*	*n*	*m*
Road	10	.005	.0005	.30	-	-
Rail	10	.002	.0001	.15	-	-
Air	200	.080	.0001	.80	-	-
Maritime	100	.050	.0001	.10	-	-
Export	-	-	-	-	20	.11
Import	-	-	-	-	20	.12
Transit-in	-	-	-	-	20	.03
Transit-out	-	-	-	-	20	.04
Pre-export	-	-	-	-	20	.16
Pre-import	-	-	-	-	20	.17
Transfer	-	-	-	-	0	.0008

ANNEX TABLE 18. FINAL SOLUTION FOR JEDDAH-BAGHDAD ORIGIN-DESTINATION PAIR

Path No.	From	To	Path flow (in tons)	Path cost (in cost units)
1	15 416 (Jeddah)	35 317 (Baghdad)	128.2907	487.7554
From	To	Cost	Mode or operation type	
15 416 (Jeddah)	10 416 (Jeddah)	0.00E+00	18 (dummy origin: Jeddah, road)	
10 416 (Jeddah)	104 (Jeddah)	40.52651	16 (pre-export)	
104 (Jeddah)	114 (Jeddah)	1.03E-01	10 (transfer: road to rail)	
114 (Jeddah)	113 (Jdedyet Ar'ar)	245.6024	2 (rail)	
113 (Jdeydet Ar'ar)	11 311 (Jdeydet Ar'ar)	34.11197	11 (export: at Jdeydet Ar'ar border point)	
11 311 (Jdeydet Ar'ar)	314 (Jdeydet Ar'ar)	13.40243	2 (rail)	
314 (Jdeydet Ar'ar)	31 412 (Jdeydet Ar'ar)	35.39488	12 (import: at Jdeydet Ar'ar border point)	
31 412 (Jdeydet Ar'ar)	313 (Baghdad)	76.70243	2 (rail)	
313 (Baghdad)	303 (Baghdad)	1.03E-01	10 (transfer: rail to road)	
303 (Baghdad)	30 317 (Baghdad)	41.80942	17 (pre-import)	
30 317 (Baghdad)	35 317 (Baghdad)	0.00E+00	18 (dummy destination: Baghdad, road)	

ANNEX TABLE 19. FINAL SOLUTION FOR RIYADH-BEIRUT ORIGIN-DESTINATION PAIR

Path No.	From	To	Path flow (in tons)	Path cost (in cost units)
1	15 016 (Riyadh)	65 117 (Beirut)	119.41559	646.2239
From	To	Cost	Mode or operation type	
15 016 (Riyadh)	10 016 (Riyadh)	0.00E+00	18 (dummy origin: Riyadh, road)	
10 016 (Riyadh)	100 (Riyadh)	51.84399	16 (pre-export)	
100 (Riyadh)	110 (Riyadh)	1.59E-01	10 (transfer: road to rail)	
110 (Riyadh)	114 (Jeddah)	155.3648	2 (rail)	
114 (Jeddah)	134 (Jeddah)	6.37E-02	10 (transfer: rail to seaport)	
134 (Jeddah)	13 411 (Jeddah)	33.13572	11 (export: at Jeddah seaport)	
13 411 (Jeddah)	631 (Beirut)	317.3968	4 (maritime)	
631 (Beirut)	63 112 (Beirut)	34.32987	12 (import: at Beirut seaport)	
63 112 (Beirut)	601 (Beirut)	9.55E-02	10 (transfer: seaport to road)	
601 (Beirut)	60 117 (Beirut)	53.83424	17 (pre-import)	
60 117 (Beirut)	65 117 (Beirut)	0.00E+00	18 (dummy destination: Beirut, road)	
2	15 016 (Riyadh)	65 117 (Beirut)	79.2978	651.1414
From	To	Cost	Mode or operation type	
15 016 (Riyadh)	10 016 (Riyadh)	0.00E+00	18 (dummy origin: Riyadh, road)	
10 016 (Riyadh)	100 (Riyadh)	51.84399	16 (pre-export)	
100 (Riyadh)	110 (Riyadh)	1.59E-01	10 (transfer: road to rail)	
110 (Riyadh)	116 (Hadithah)	232.343	2 (rail)	
116 (Hadithah)	11 611 (Hadithah)	24.36138	11 (export: at Hadithah border point)	
11 611 (Hadithah)	514 (Omari)	11.7365	2 (rail)	
514 (Omari)	51 413 (Omari)	22.38828	13 (transit-in: at Omari border point)	
51 413 (Omari)	512 (Amman)	37.04298	2 (rail)	
512 (Amman)	513 (Jaber)	27.89298	2 (rail0	
513 (Jaber)	51 314 (Jaber)	23.18438	14 (transit-out: at Jaber border point)	
51 314 (Jaber)	412 (Nasib)	12.29298	2 (rail)	
412 (Nasib)	41 213 (Nasib)	22.38828	13 (transit-in: at Nasib border point)	
41 213 (Nasib)	411 (Damascus)	26.39298	2 (rail)	
411 (Damascus)	413 (Jdeydet Yabus)	18.59299	2 (rail)	
413 (Jdeydet Yabus)	41 314 (Jdeydet Yabus)	23.18438	14 (transit-out: at Jdeydet Yabus border point)	
41 314 (Jdeydet Yabus)	610 (Masna)	12.29298	2 (rail)	
610 (Masna)	61 012 (Masna)	29.55313	12 (import: at Masna border point)	
61 012 (Masna)	611 (Beirut)	21.59299	2 (rail)	
611 (Beirut)	601 (Beirut)	6.37E-02	10 (transfer: rail to road)	
601 (Beirut)	60117 (Beirut)	53.83424	17 (pre-import)	
60 117 (Beirut)	65 117 (Beirut)	0.00E+00	18 (dummy destination: Beirut, road)	

ANNEX TABLE 20. FINAL SOLUTION FOR DAMASCUS-KUWAIT ORIGIN-DESTINATION PAIR

Path No.	From	To	Path flow (in tons)	Path cost (in cost units)
1	45 116 (Damascus)	25 117 (Kuwait)	127.7063	560.7977
From	To	Cost	Mode or operation type	
45 116 (Damascus)	40 116 (Damascus)	0.00E+00	18 (dummy origin: Damascus, road)	
40 116 (Damascus)	401 (Damascus)	75.13011	16 (pre-export)	
401 (Damascus)	411 (Damascus)	2.76E-01	10 (transfer: road to rail)	
411 (Damascus)	410 (Tanf)	113.1363	2 (rail)	
410 (Tanf)	41 011 (Tanf)	34.0477	11 (export: at Tanf border point)	
41 011 (Tanf)	315 (Al-Walid)	13.3863	2 (rail)	
315 (Al-Walid)	31 513 (Al-Walid)	23.83119	13 (transit-in: at Al-Walid border point)	
31 513 (Al-Walid)	313 (Baghdad)	64.38631	2 (rail)	
313 (Baghdad)	311 (Safwan)	91.0863	2 (rail)	
311 (Safwan)	31 114 (Safwan)	25.10825	14 (transit-out: at Jdeydet Yabus border point)	
31 114 (Safwan)	212 (Abdali)	13.3863	2 (rail)	
212 (Abdali)	21 212 (Abdali)	35.32476	12 (import: at Abdali border point)	
21 212 (Abdali)	211 (Kuwait)	29.8863	2 (rail)	
211 (Kuwait)	201 (Kuwait)	1.02E-01	10 (transfer: rail to road)	
201 (Kuwait)	20 117 (Kuwait)	41.71008	17 (pre-import)	
20 117 (Kuwait)	25 117 (Kuwait)	0.00E+00	18 (dummy destination: Damascus, road)	

ANNEX TABLE 21. FINAL SOLUTION FOR DAMASCUS-JEDDAH ORIGIN-DESTINATION PAIR

Path No.	From	To	Path flow (in tons)	Path cost (in cost units)
1	45 116 (Damascus)	15 417 (Jeddah)	141.46371	593.7285
From	To	Cost	Mode or operation type	
45 116 (Damascus)	40 116 (Damascus)	0.00E+00	18 (dummy origin: Damascus road)	
40 116 (Damascus)	401 (Damascus)	75.13011	16 (pre-export)	
401 (Damascus)	411 (Damascus)	2.76E-01	10 (transfer: road to rail)	
411 (Damascus)	412 (Nasib)	27.88413	2 (rail)	
412 (Nasib)	41 211 (Nasib)	35.56101	11 (export: at Nasib border point)	
41 211 (Nasib)	513 (Jaber)	13.78413	2 (rail)	
513 (Jaber)	51 313 (Jaber)	24.24391	13 (transit-in: at Jaber border point)	
51 313 (Jaber)	512 (Amman)	29.38413	2 (rail)	
512 (Amman)	511 (Al-Mudawwarah)	61.78413	2 (rail)	
511 (Al-Mudawwarah)	51 114 (Al-Mudawwarah)	25.65855	14 (transit-out: at Al-Mudawwarah border point)	
51 114 (Al-Mudawwarah)	115 (Halat Ammar)	13.78413	2 (rail)	
115 (Halat Ammar)	11 512 (Halat Ammar)	36.97565	12 (import: at Halat Ammar border point)	
11 512 (Halat Ammar)	114 (Jeddah)	192.2841	2 (rail)	
114 (Jeddah)	104 (Jeddah)	1.13E-01	10 (transfer: rail to road)	
104 (Jeddah)	10 417 (Jeddah)	56.86567	17 (pre-import)	
10417 (Jeddah)	15 417 (Jeddah)	0.00E+00	18 (dummy destination: Jeddah, road)	
2	45 116 (Damascus)	15 417 (Jeddah)	75.39318	601.6109
From	To	Cost	Mode or operation type	
45 116 (Damascus)	40 116 (Damascus)	0.00E+00	18 (dummy origin: Damascus, road)	
40 116 (Damascus)	401 (Damascus)	75.13011	16 (pre-export)	
401 (Damascus)	411 (Damascus)	2.76E-01	10 (transfer: road to rail)	
411 (Damascus)	413 (Jedeidat Yabus)	18.5192	2 (rail)	
413 (Jdeydet Yabus)	41 311 (Jdeydet Yabus)	28.29325	11 (export: at Jedeidat Yabus border point)	
41 311 (Jdeydet Yabus)	610 (Masna)	12.2192	2 (rail)	
610 (Masna)	61 013 (Masna)	22.2618	13 (transit-in: at Masna border point)	
61 013 (Masna)	611 (Beirut)	21.5192	2 (rail)	
611 (Beirut)	631 (Beirut)	2.75E-02	10 (transfer: rail to seaport)	
631 (Beirut)	63 114 (Beirut)	23.01573	14 (transit-out: at Beirut seaport)	
63 114 (Beirut)	134 (Jeddah)	314.3381	4 (maritime)	
134 (Jeddah)	13 412 (Jeddah)	29.04718	12 (import: at Jeddah seaport)	
13 412 (Jeddah)	104 (Jeddah)	6.03E-02	10 (transfer: seaport to road)	
104 (Jeddah)	10 417 (Jeddah)	56.86567	17 (pre-import)	
10 417 (Jeddah)	15 417 (Jeddah)	0.00E+00	18 (dummy destination: Jeddah, road)	

ANNEX TABLE 22. FINAL FLOW PATTERN

From	To	Flow	Cost	Operation or mode type
11 611 (Hadithah)	514 (Omari)	39.6489	11.74	2 (rail)
41 311 (Jdeydet Yabus)	610 (Masna)	75.39317	12.22	2 (rail)
61 013 (Masna)	611 (Beirut)	75.39317	21.52	2 (rail)
110 (Riyadh)	116 (Hadithah)	79.60938	232.34	2 (rail)
411 (Damascus)	413 (Jdeydet Yabus)	79.60938	18.59	2 (rail)
512 (Amman)	513 (Jaber)	79.60938	27.89	2 (rail)
41 213 (Nasib)	411 (Damascus)	79.60938	26.39	2 (rail)
41 314 (Jdeydet Yabus)	610 (Masna)	79.60938	12.29	2 (rail)
51314 (Jaber)	412 (Nasib)	79.60938	12.29	2 (rail)
51 413 (Omari)	512 (Amman)	79.60938	37.04	2 (rail)
61 012 (Masna)	611 (Beirut)	79.60938	21.59	2 (rail)
110 (Riyadh)	114 (Jeddah)	119.4156	155.36	2 (rail)
313 (Baghdad)	311 (Safwan)	127.7063	91.09	2 (rail)
411 (Damascus)	410 (Tanf)	127.7063	113.14	2 (rail)
21 212 (Abdali)	211 (Kuwait)	127.7063	29.89	2 (rail)
31 114 (Safwan)	212 (Abdali)	127.7063	13.39	2 (rail)
31 513 (Al-Walid)	313 (Baghdad)	127.7063	64.39	2 (rail)
41 011 (Tanf)	315 (Al-Walid)	127.7063	13.39	2 (rail)
114 (Jeddah)	113 (Jdeydet Ar'ar)	128.2907	245.60	2 (rail)
113 11 (Jdeydet Ar'ar)	314 (Jdeydet Ar'ar)	128.2907	13.40	2 (rail)
31 412 (Jedeidat Ar'ar)	313 (Baghdad)	128.2907	76.70	2 (rail)
411 (Damascus)	412 (Nasib)	141.4637	27.88	2 (rail)
512 (Amman)	511 (Al-Mudawwarah)	141.4637	61.78	2 (rail)
11 512 (Halat Ammar)	114 (Jeddah)	141.4637	192.28	2 (rail)
41 211 (Nasib)	513 (Jaber)	141.4637	13.78	2 (rail)
51 114 (Al-Mudawwarah)	115 (Halat Ammar)	141.4637	13.78	2 (rail)
51 313 (Jaber)	512 (Amman)	141.4637	29.38	2 (rail)
63 114 (Beirut)	134 (Jeddah)	75.39317	314.34	2 (rail)
13 411 (Jeddah)	631 (Beirut)	119.4156	317.40	2 (rail)
611 (Beirut)	631 (Beirut)	34.42892	0.03	10 (transfer: rail to road)
114 (Jeddah)	104 (Jeddah)	39.80438	0.03	10 (transfer: rail to road)
116 (Hadithah)	106 (Hadithah)	39.96048	0.03	10 (transfer: rail to road)
601 (Beirut)	631 (Beirut)	40.96425	0.03	10 (transfer: rail to road)
13 412 (Jeddah)	104 (Jeddah)	75.39317	0.06	10 (transfer: rail to road)
611 (Beirut)	601 (Beirut)	79.60938	0.06	10 (transfer: rail to road)
114 (Jeddah)	134 (Jeddah)	79.61121	0.06	10 (transfer: rail to road)
63 112 (Beirut)	601 (Beirut)	119.4156	0.10	10 (transfer: rail to road)
211 (Kuwait)	201 (Kuwait)	127.7063	0.10	10 (transfer: rail to road)
104 (Jeddah)	114 (Jeddah)	128.2907	0.10	10 (transfer: rail to road)
313 (Baghdad)	303 (Baghdad)	128.2907	0.10	10 (transfer: rail to road)
100 (Riyadh)	110 (Riyadh)	199.025	0.16	10 (transfer: rail to road)
401 (Damascus)	411 (Damascus)	344.5632	0.28	10 (transfer: rail to road)
116 (Hadithah)	11 611 (Hadithah)	39.6489	24.36	11 (export: at Hadithah border point)
413 (Jdeydet Yabus)	41 311 (Jdeydet Yabus)	75.39317	28.29	11 (export: at Jdeydet Yabus border point)
134 (Jeddah)	13411 (Jeddah)	119.4156	33.14	11 (export: at Jeddah seaport)
410 (Tanf)	41 011 (Tanf)	127.7063	34.05	11 (export: at Tanf border point)
113 (Jdeydet Ar'ar)	11 311 (Jdeydet Ar'ar)	128.2907	34.11	11 (export: at Jdeydet Ar'ar border point)
412 (Nasib)	41 211 (Nasib)	141.4637	35.56	11 (export: at Nasib border point)
134 (Jeddah)	13 412 (Jeddah)	75.39317	29.05	12 (import: at Jeddah seaport)
610 (Masna)	61 012 (Masna)	79.60938	29.55	12 (import: at Masna border point)

ANNEX TABLE 22 (*continued*)

From	To	Flow	Cost	Operation or mode type
631 (Beirut)	63 112 (Beirut)	119.4156	34.33	12 (import: at Beirut seaport)
212 (Abdali)	21 212 (Abdali)	127.7063	35.32	12 (import: at Abdali border point)
314 (Jdeydet Ar'ar)	31 412 (Jdeydet Ar'ar)	128.2907	35.39	12 (import: at Jdeydet Ar'ar border point)
115 (Halat Ammar)	11 512 (Halat Ammar)	141.4637	36.98	12 (import: at Halat Ammar border point)
610 (Masna)	61 013 (Masna)	75.39317	22.26	13 (transit-in: at Masna border point)
412 (Nasib)	41 213 (Nasib)	79.60938	22.39	13 (transit-in: at Nasib border point)
315 (Al-Walid)	31 513 (Al-Walid)	127.7063	23.83	13 (transit-in: at Al-Walid border point)
513 (Jaber)	51313 (Jaber)	141.4637	24.24	13 (transit-in: at Jaber border point)
514 (Omari)	51 413 (Omari)	79.60938	22.39	13 (transit-in: at Omari border point)
631 (Beirut)	63 114 (Beirut)	75.39317	23.02	14 (transit-out: at Beirut seaport)
413 (Jdeydet Yabus)	41 314 (Jdeydet Yabus)	79.60938	23.18	14 (transit-out: at Jdeydet Yabus border point)
513 (Jaber)	51 314 (Jaber)	79.60938	23.18	14 (transit-out: at Jaber border point)
311 (Safwan)	31 114 (Safwan)	127.7063	25.11	14 (transit-out: at Safwan border point)
511 (Al-Mudawwarah)	51 114 (Al-Mudawwarah)	141.4637	25.66	14 (transit-out: at al-Mudawwarah border point)
10 416 (Jeddah)	104 (Jeddah)	128.2907	40.53	16 (pre-export)
10 016 (Riyadh)	100 (Riyadh)	199.025	51.84	16 (pre-export)
40 116 (Damascus)	401 (Damascus)	344.5632	75.13	16 (pre-export)
201 (Kuwait)	20 117 (Kuwait)	127.7063	41.71	17 (pre-import)
303 (Baghdad)	30 317 (Baghdad)	128.2907	41.81	17 (pre-import)
601 (Beirut)	60 117 (Beirut)	199.025	53.83	17 (pre-import)
104 (Jeddah)	10 417 (Jeddah)	216.8569	56.87	17 (pre-import)
20 117 (Kuwait)	25 117 (Kuwait)	127.7063	0.00	18 (dummy destination: Damascus, road)
15 416 (Jeddah)	10 416 (Jeddah)	128.2907	0.00	18 (dummy origin: Jeddah, road)
30 317 (Baghdad)	35 317 (Baghdad)	128.2907	0.00	18 (dummy destination: Baghdad, road)
15 016 (Riyadh)	10 016 (Riyadh)	199.025	0.00	18 (dummy origin: Riyadh, road)
60 117 (Beirut)	65 117 (Beirut)	199.025	0.00	18 (dummy destination: Beirut, road)
10 417 (Jeddah)	15 417 (Jeddah)	216.8569	0.00	18 (dummy destination: Jeddah, road)
45 116 (Damascus)	40 116 (Damascus)	344.5632	0.00	18 (dummy origin: Damascus, road)

ANNEX TABLE 23. PATH FLOWS
(*Tons*)

Origin-destination	Path 1 flow	Path 2 flow	Total
Jeddah-Baghdad	128.2907	—	128.2907
Riyadh-Beirut	119.41559	79.60938	199.025
Damascus-Kuwait	127.7063	—	127.7063
Damascus-Jeddah	141.46371	75.39318	216.8569
Total network flow			671.8789

ANNEX TABLE 24. TRIP DISTRIBUTION FLOWS
(*Tons*)

From/to	Jeddah	Riyadh	Damascus	Kuwait	Baghdad	Beirut	Total
Jeddah	—	0	0	0	128.2907	0	128.2907
Riyadh	0	—	0	0	0	199.025	199.025
Damascus	216.8569	0	—	127.7063	0	0	344.5632
Kuwait	0	0	0	—	0	0	0
Baghdad	0	0	0	0	—	0	0
Beirut	0	0	0	0	0	—	0
Total	216.8569	0	0	127.7063	128.2907	199.025	671.8789

ANNEX TABLE 25. PATH UNIT COSTS
(Cost units)

Origin-destination	Path 1 cost	Path 2 cost
Jeddah-Baghdad	487.7554	—
Riyadh-Beirut	646.2239	651.1414
Damascus-Kuwait	560.7977	—
Damascus-Jeddah	593.7285	601.6109

ANNEX TABLE 26. PATH TOTAL COSTS
(Cost units)

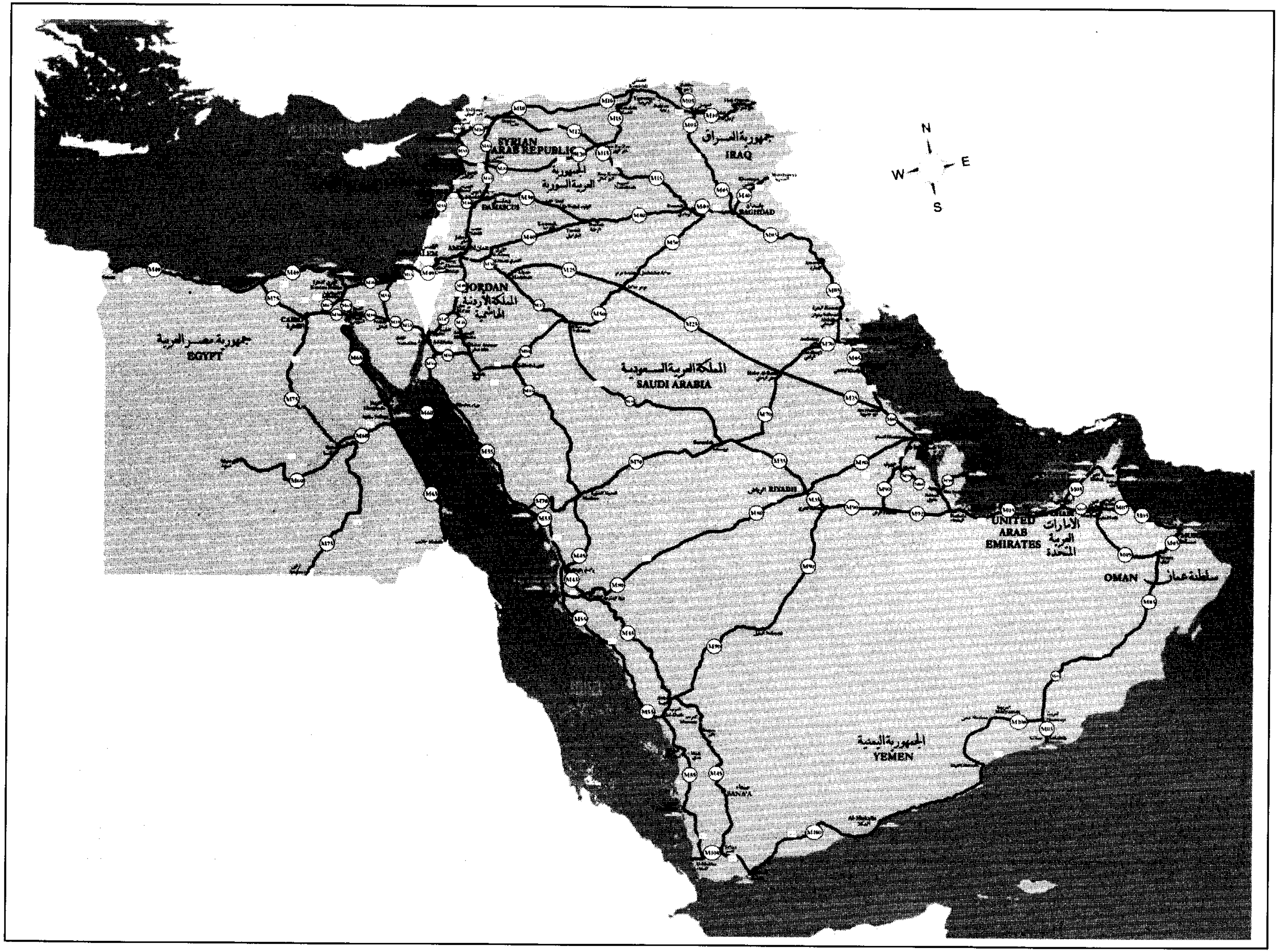
Origin-destination	Path 1 flow	Path 1 (unit cost)	Path 1 (total cost)	Path 2 flow	Path 2 (unit cost)	Path 2 (total cost)	Origin-destination (total cost)
Jeddah-Baghdad	128.29	487.76	62 574.48	0.00	0.00	0.00	62 574.48
Riyadh-Beirut	119.42	646.22	77 169.21	79.61	651.14	51 836.96	12 9006.17
Damascus-Kuwait	127.71	560.80	71 617.40	0.00	0.00	0.00	71 617.40
Damascus-Jeddah	141.46	593.73	83 991.04	75.39	601.61	45 357.36	12 9348.40
Total							39 2546.45

ANNEX TABLE 27. TRIP DISTRIBUTION COSTS
(Cost units)

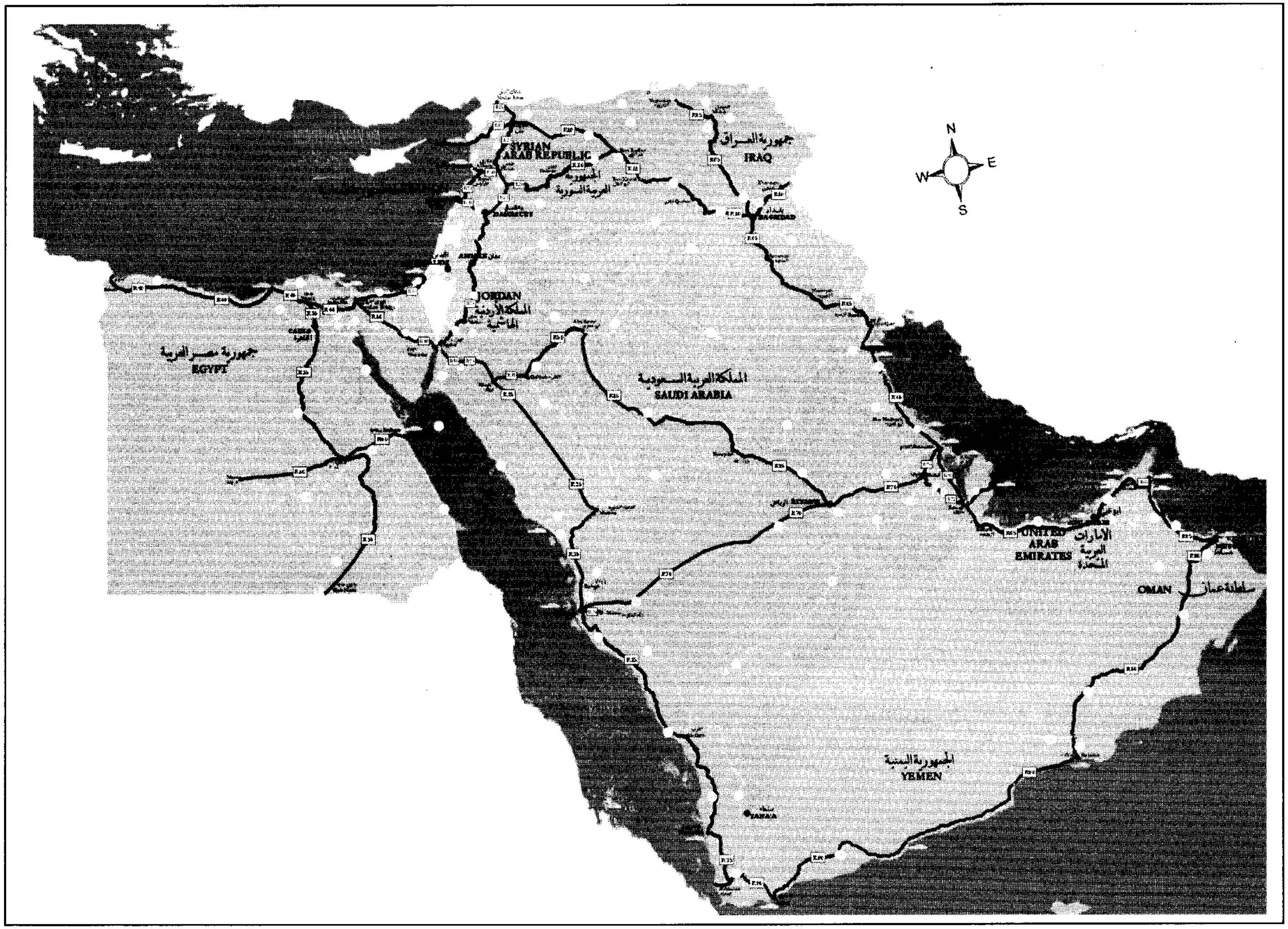
From/to	Jeddah	Riyadh	Damascus	Kuwait	Baghdad	Beirut	Total
Jeddah	-	-	-	-	62 574.48	-	62 574.48
Riyadh	-	-	-	-	-	129 006.17	129 006.17
Damascus	129 348.40	-	-	71 617.40	-	-	200 965.8
Kuwait	-	-	-	-	-	-	-
Baghdad	-	-	-	-	-	-	-
Beirut	-	-	-	-	-	-	-
Total	-	-	-	-	-	-	392 546.45

ANNEX FIGURES

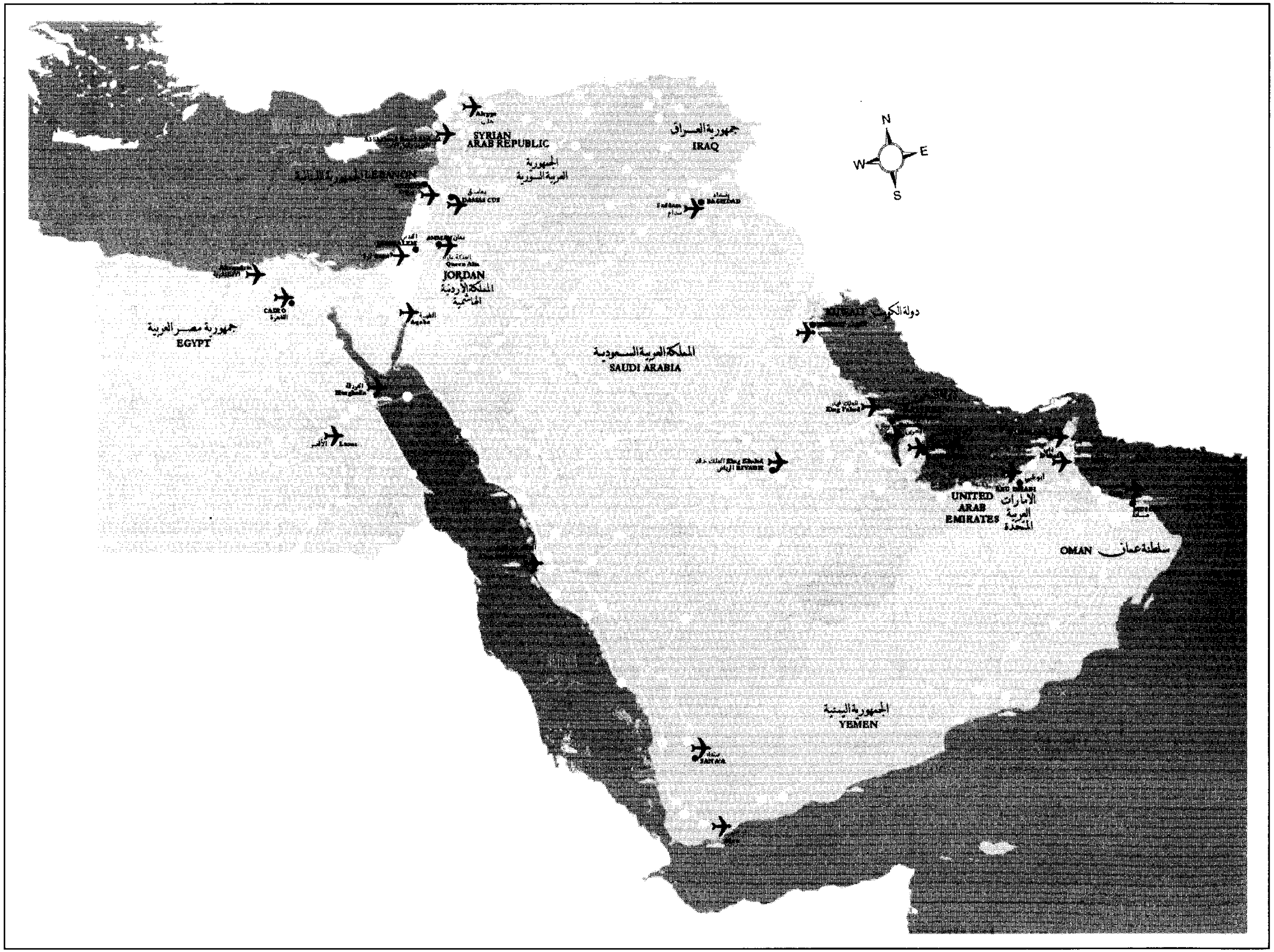
Annex figure I. International road network in Arab Mashreq



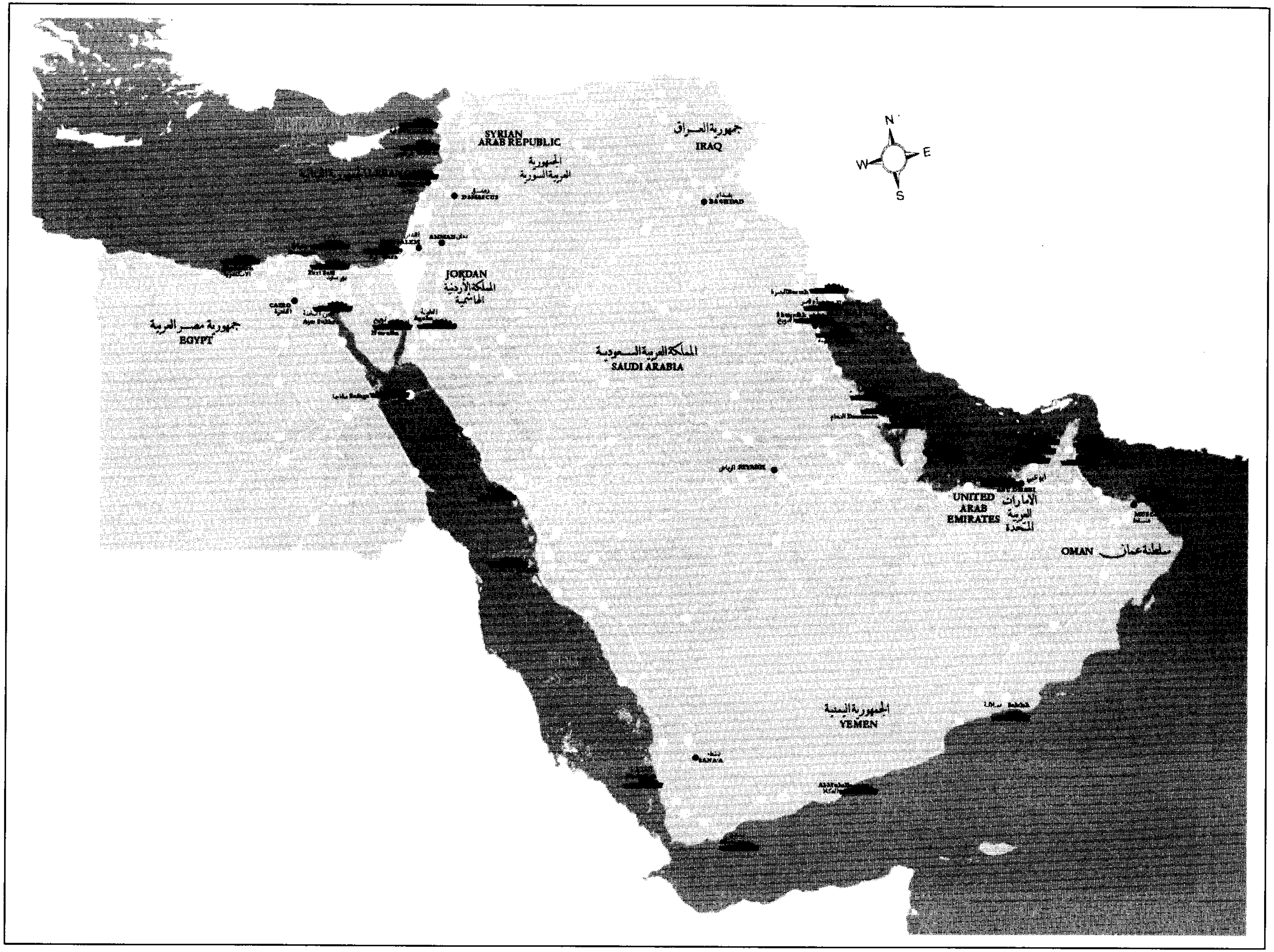
Annex figure II. International rail network in Arab Mashreq



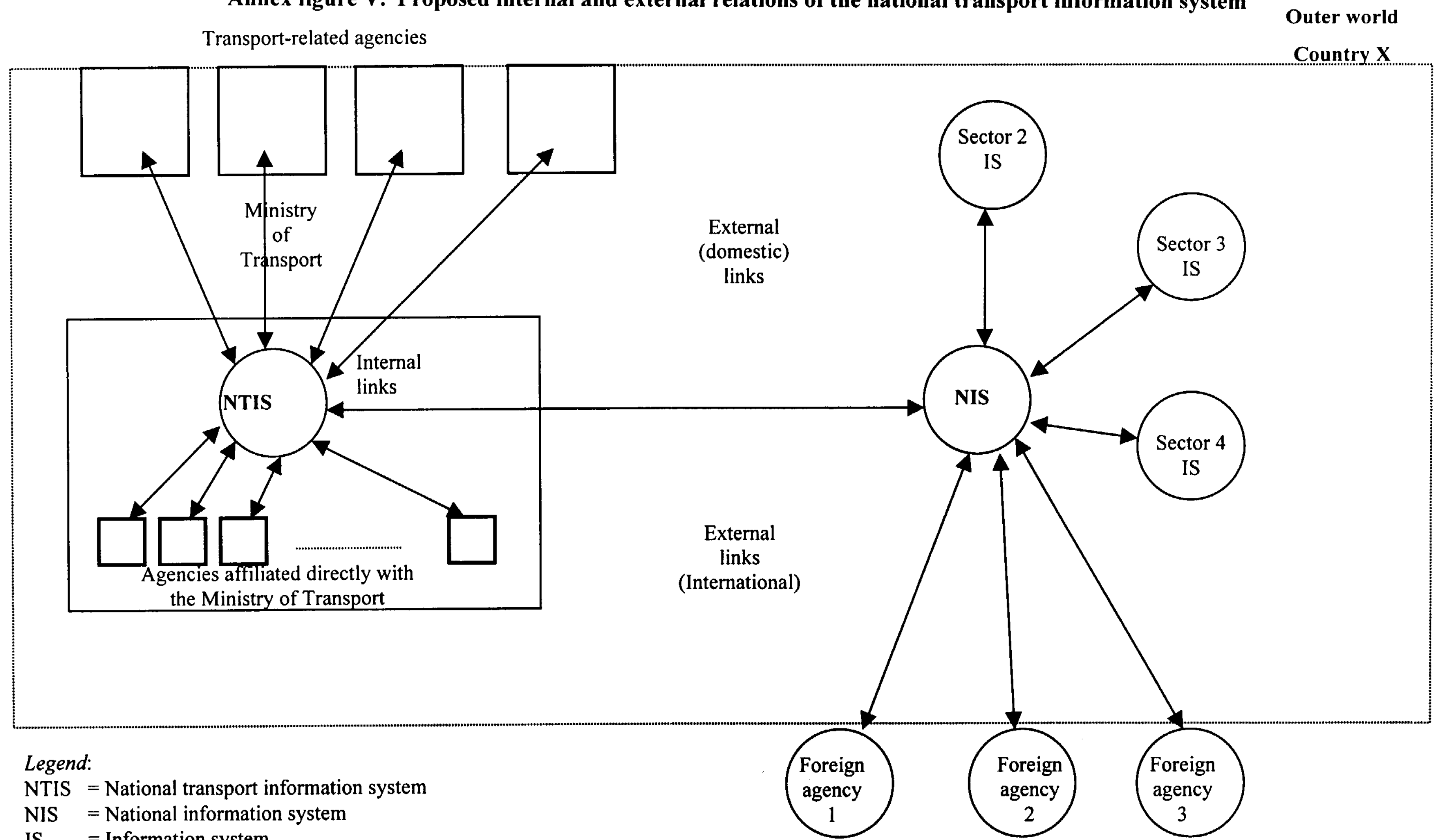
Annex figure III. Major airports in Arab Mashreq



Annex figure IV. Major seaports in Arab Mashreq



Annex figure V. Proposed internal and external relations of the national transport information system



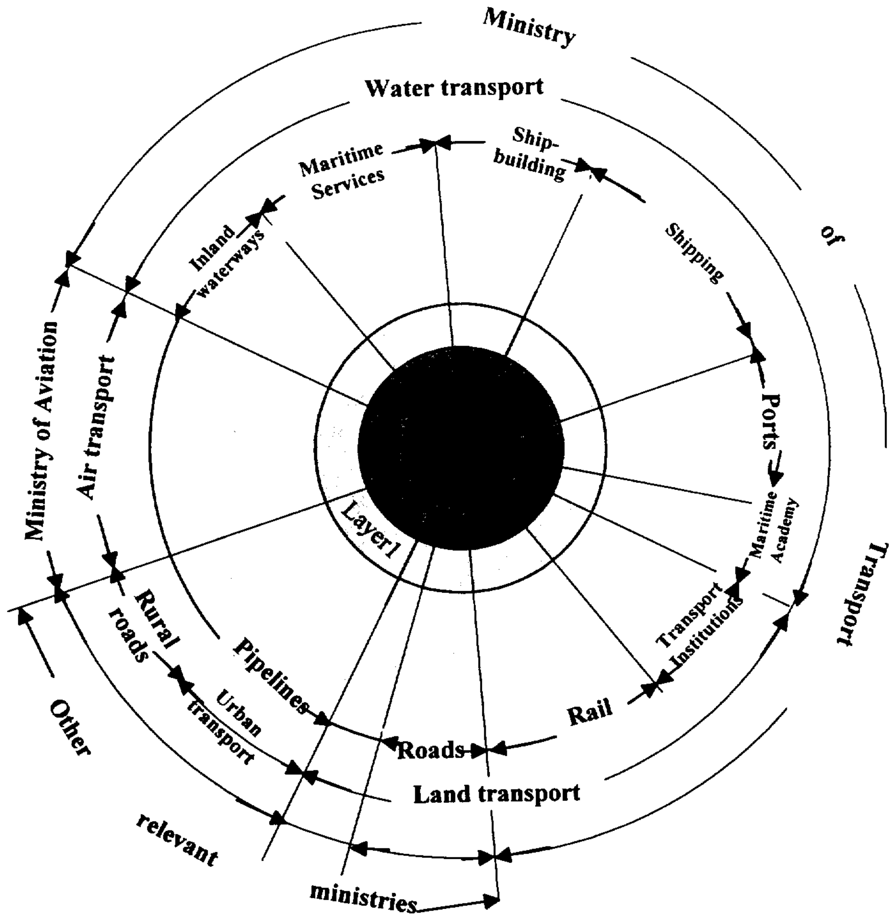
Legend:

NTIS = National transport information system

NIS = National information system

IS = Information system

Annex figure VI. Scope and coverage of the different layers of an integrated transport sector information system



Layer 1 = operational activities (data/applications) for the daily operations of the relevant transport agency

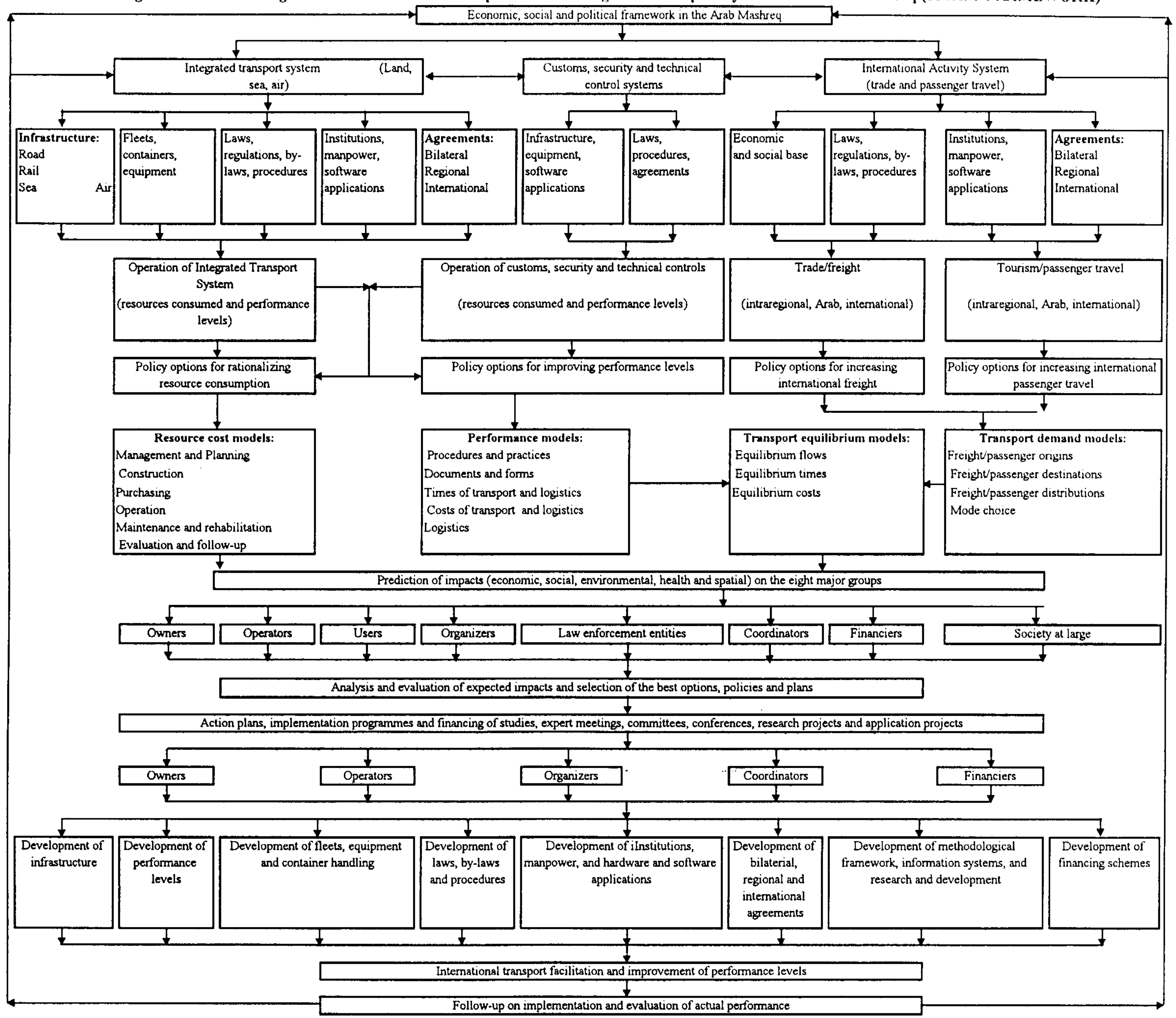
Layer 2 = managerial activities (data/applications); management information system (MIS)

} Carried out in the appropriate department of the relevant transport agency

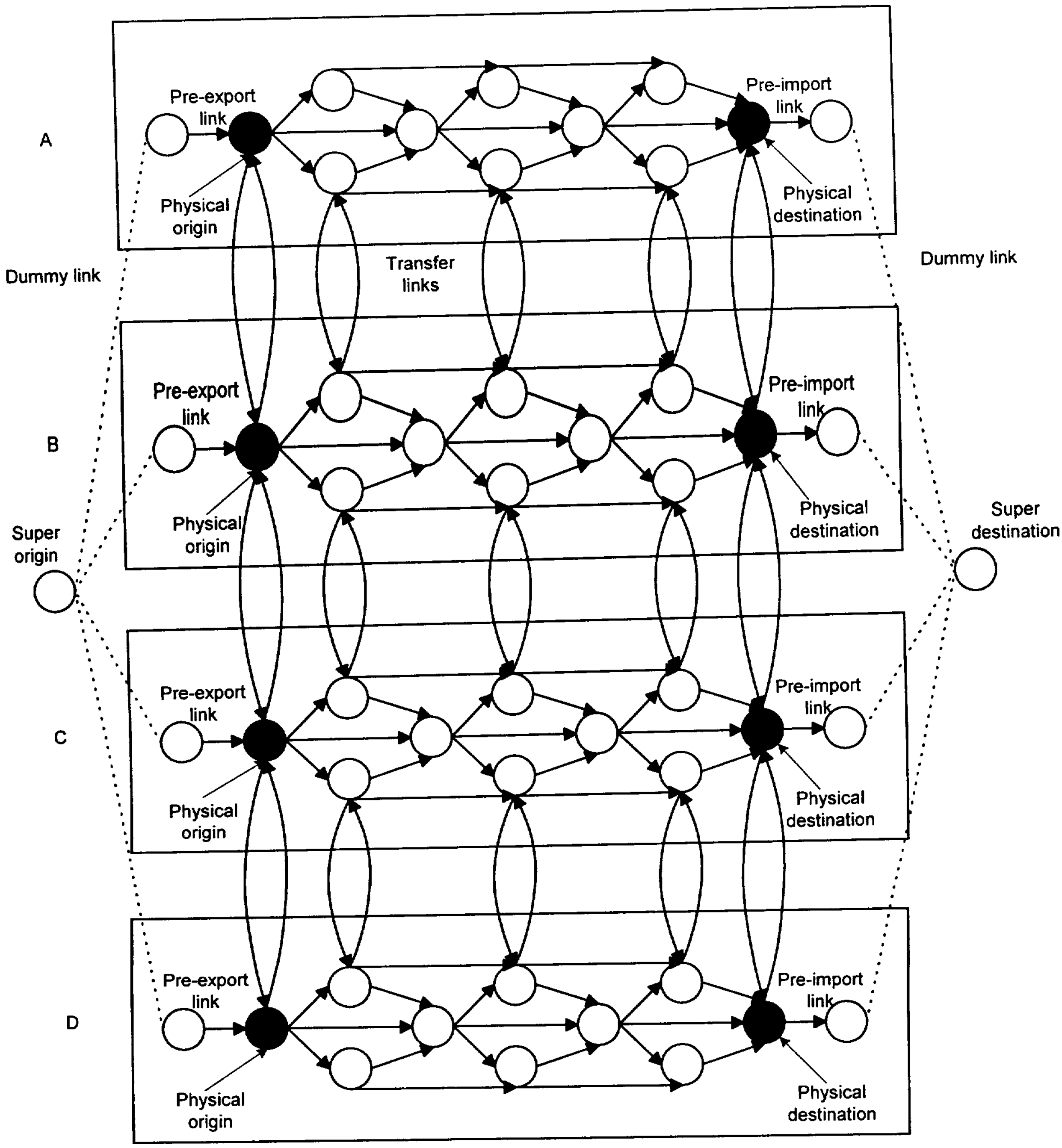
Layer 3 = transport policy and planning (data/applications); decision support system (DSS) for the relevant transport agency

} Carried out in the planning department of the ministry of transport

Annex figure VII. Methodological framework for the development of the Integrated Transport System in the Arab Mashreq (ITSAM-FRAMEWORK)

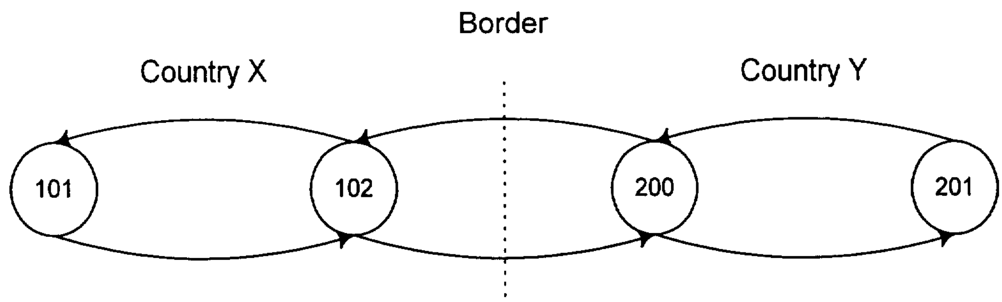


Annex figure VIII. Multimodal origin-destination pair network

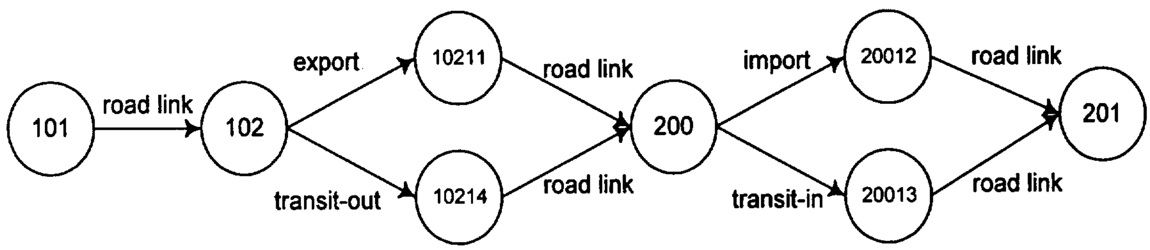


Note: A = Origin-destination (O-D) pair for road network
B = O-D pair for rail network
C = O-D pair for air network
D = O-D pair for maritime network

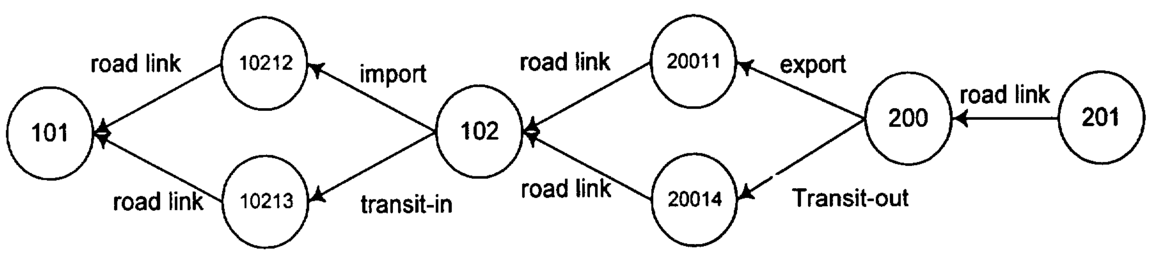
Annex figure IX. Representation of border-point administrative and logistical operations for a road network



(a) Physical road network

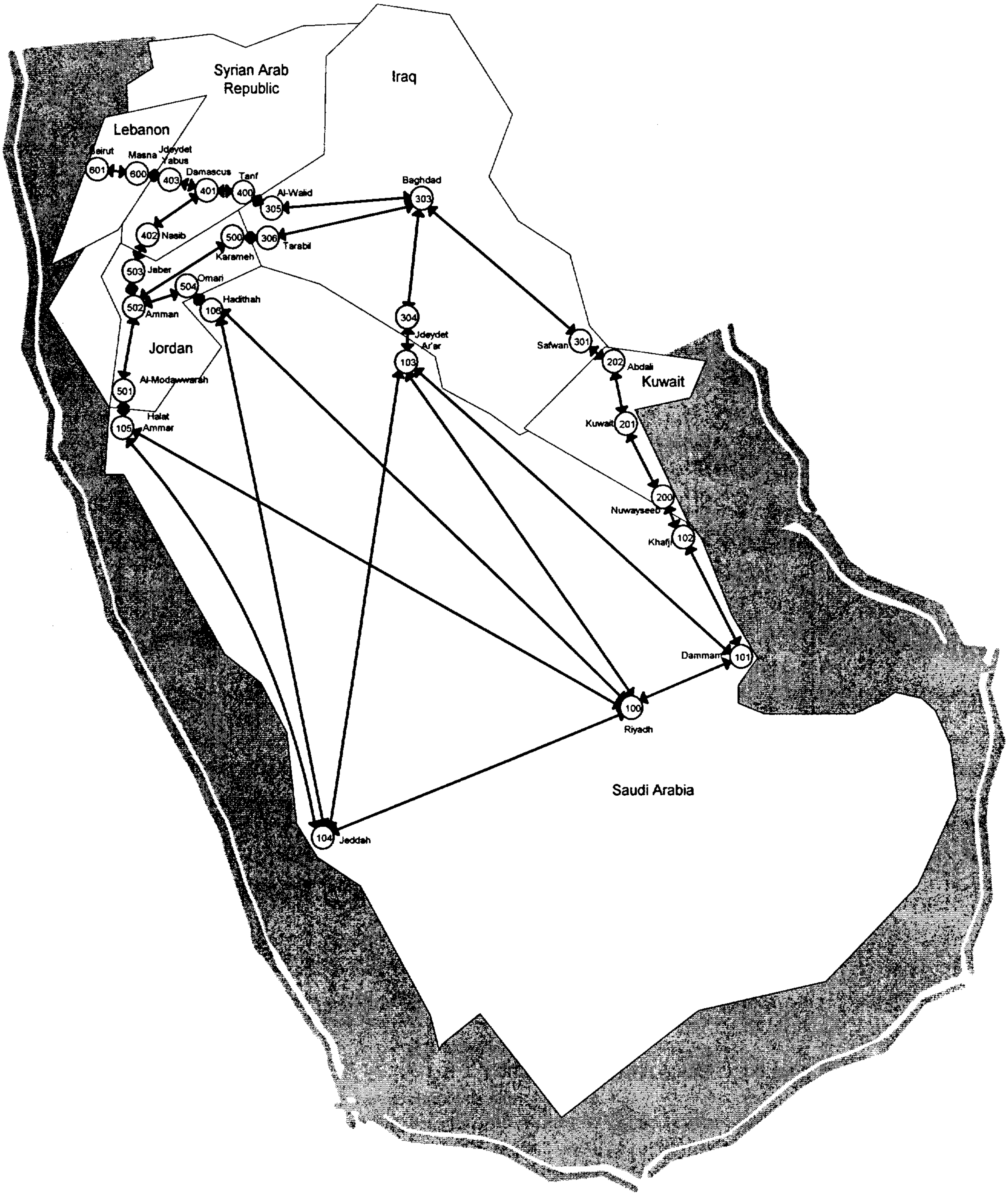


(b) A possible directed ALO from country X to country Y



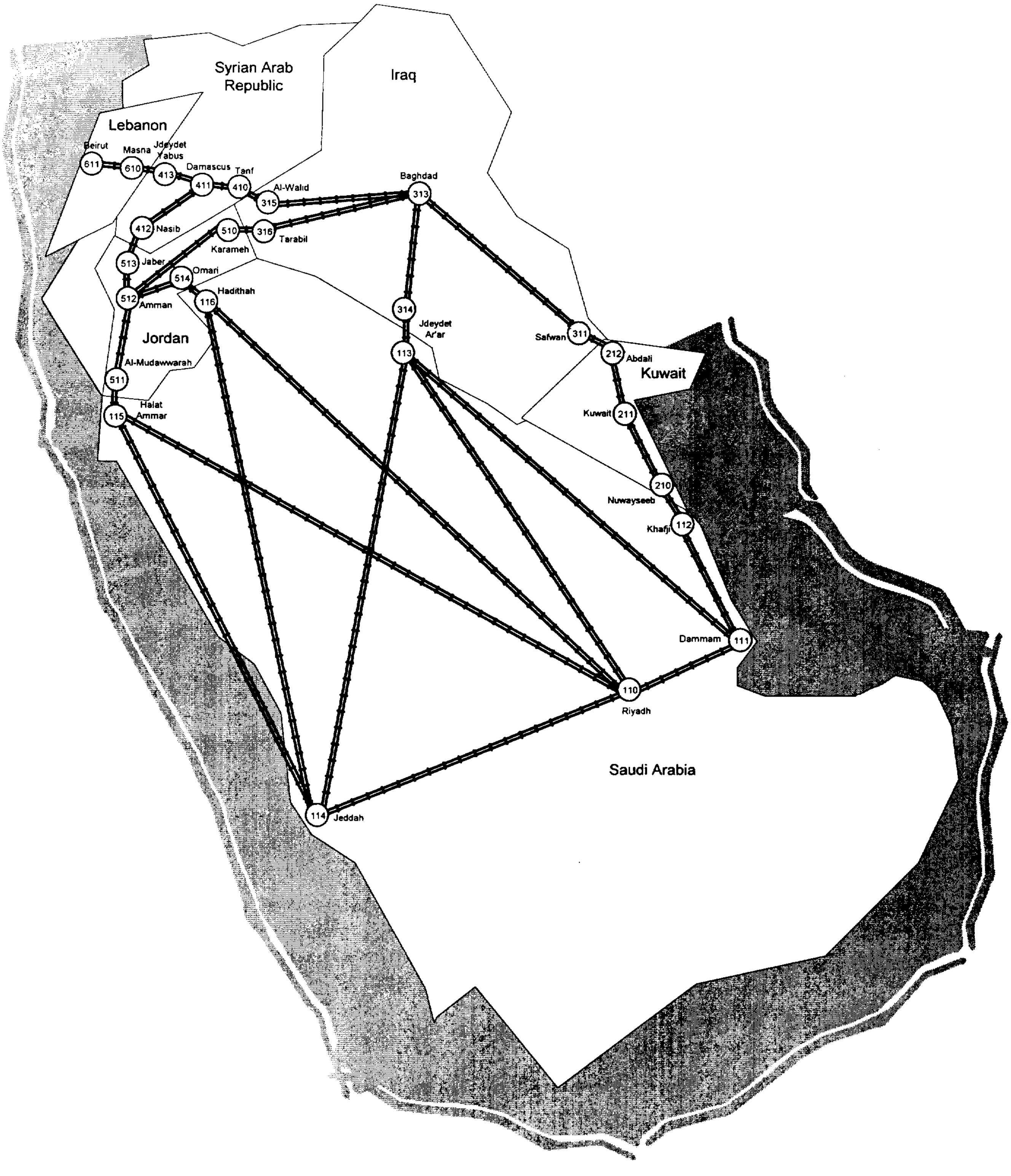
(c) A possible directed ALO from country Y to country X

Annex figure X. Road network for the prototype



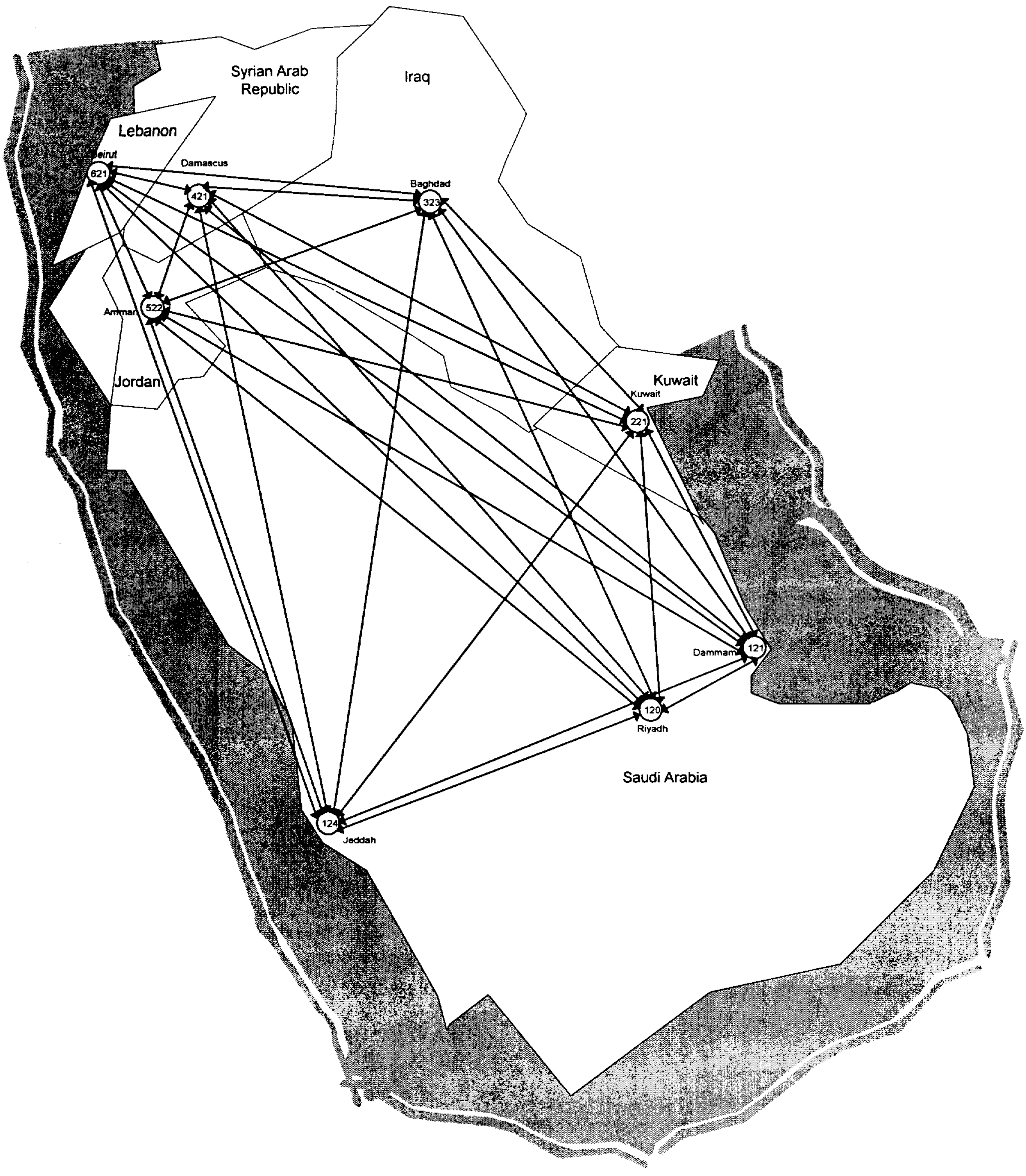
Note: The boundaries shown in this diagram are purely schematic.

Annex figure XI. Rail network for the prototype



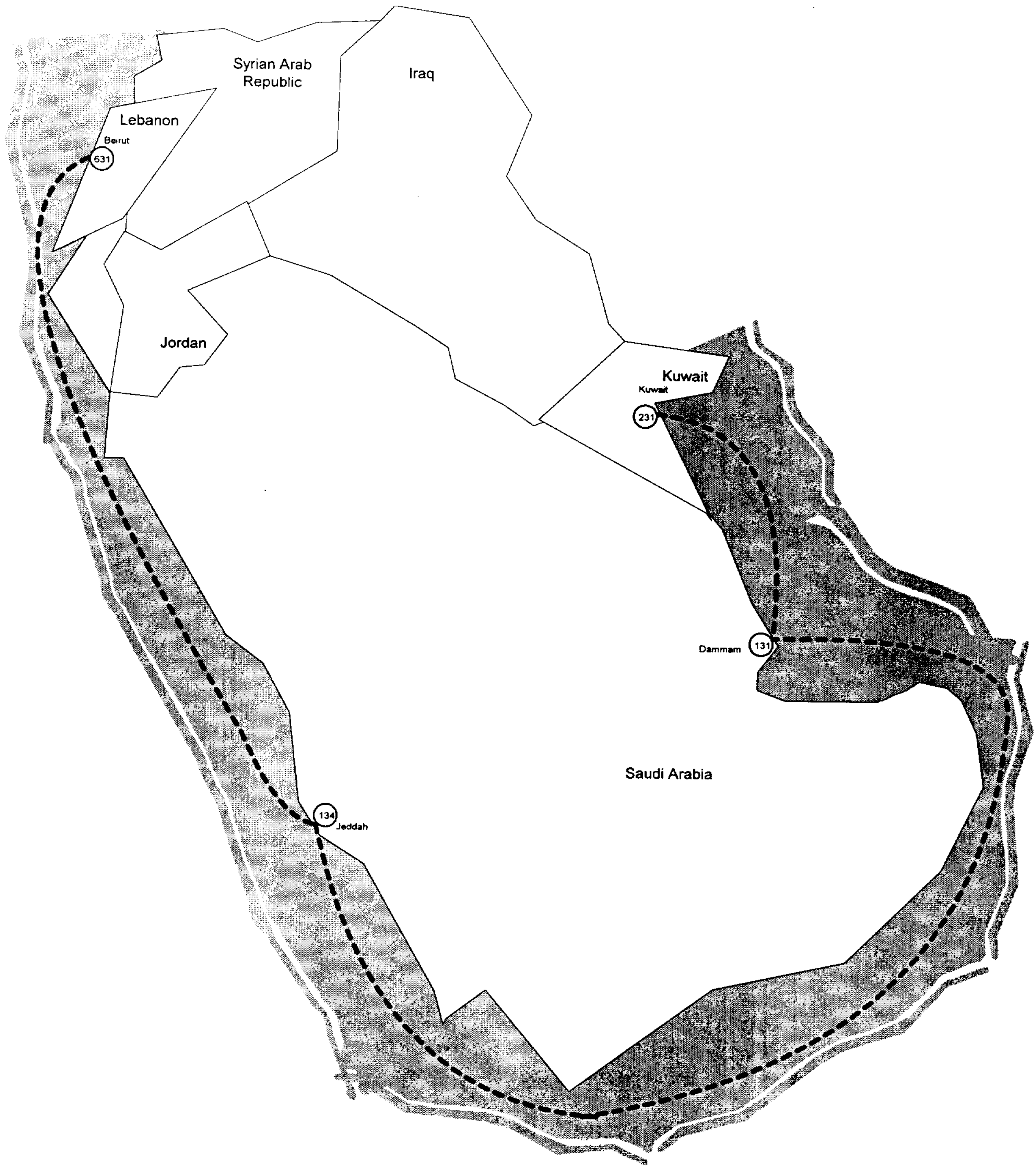
Note: The boundaries shown in this diagram are purely schematic.

Annex figure XII. Air network for the prototype



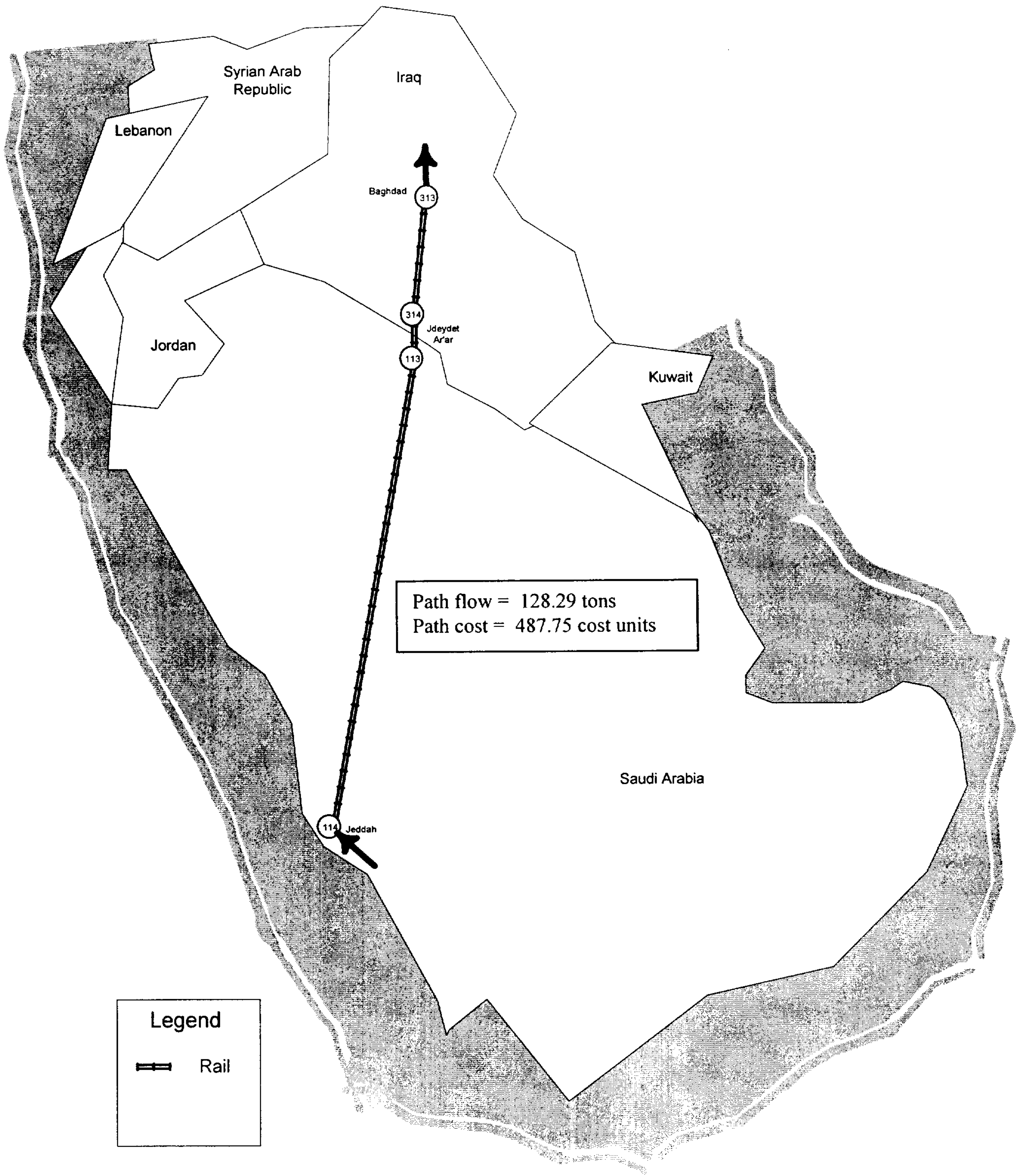
Note: The boundaries shown in this diagram are purely schematic.

Annex figure XIII. Maritime network for the prototype



Note: The boundaries shown in this diagram are purely schematic.

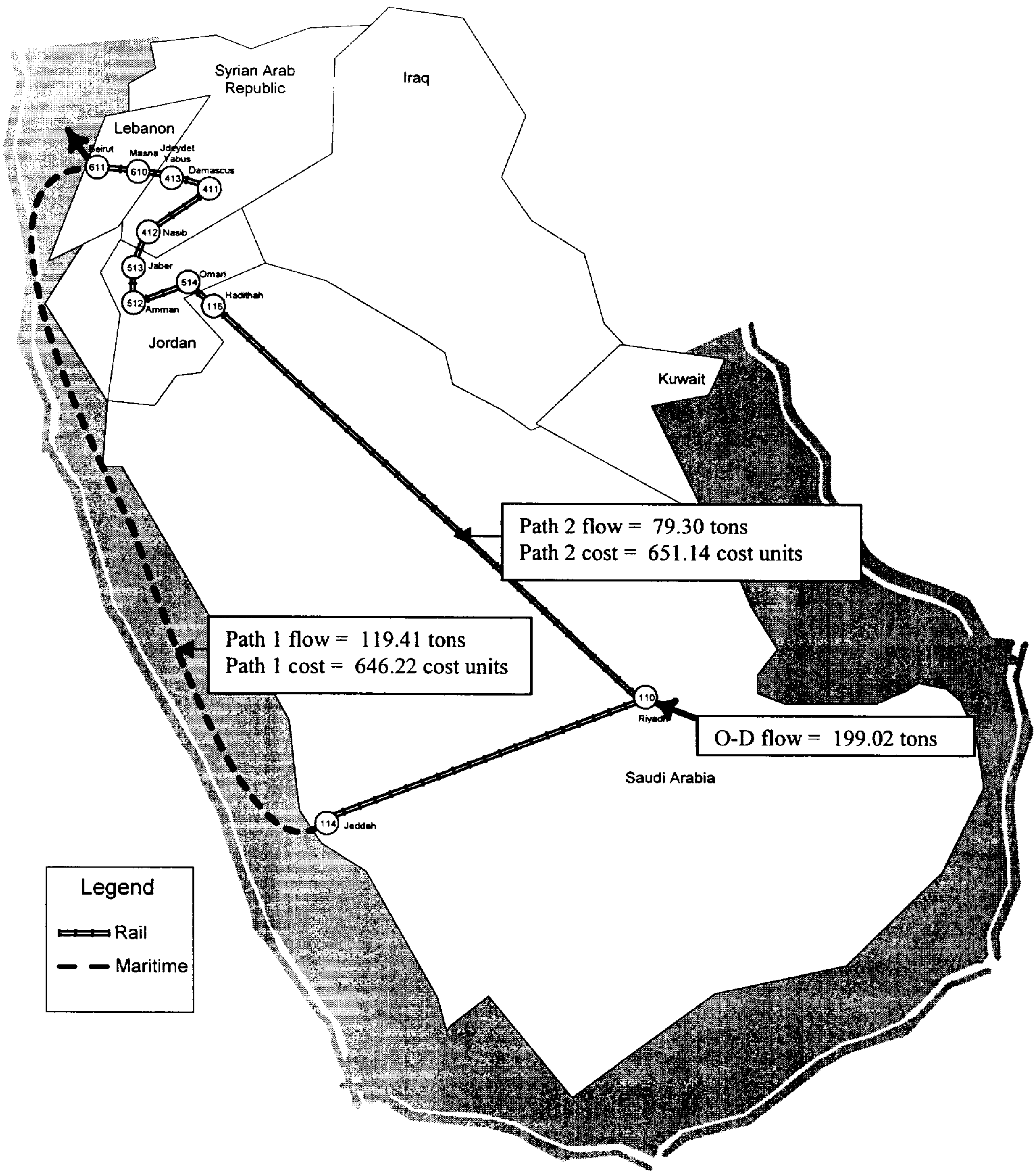
Annex figure XIV. Final solution for Jeddah-Baghdad origin-destination pair



Path 1: Jeddah $\xrightarrow[rail]{}$ Jdeydet Ar'ar (Saudi Arabia) $\xrightarrow[rail]{}$ Jdeydet Ar'ar (Iraq) $\xrightarrow[rail]{}$ Baghdad

Note: The boundaries shown in this diagram are purely schematic.

Annex figure XV. Final solution for Riyadh-Beirut origin-destination pair

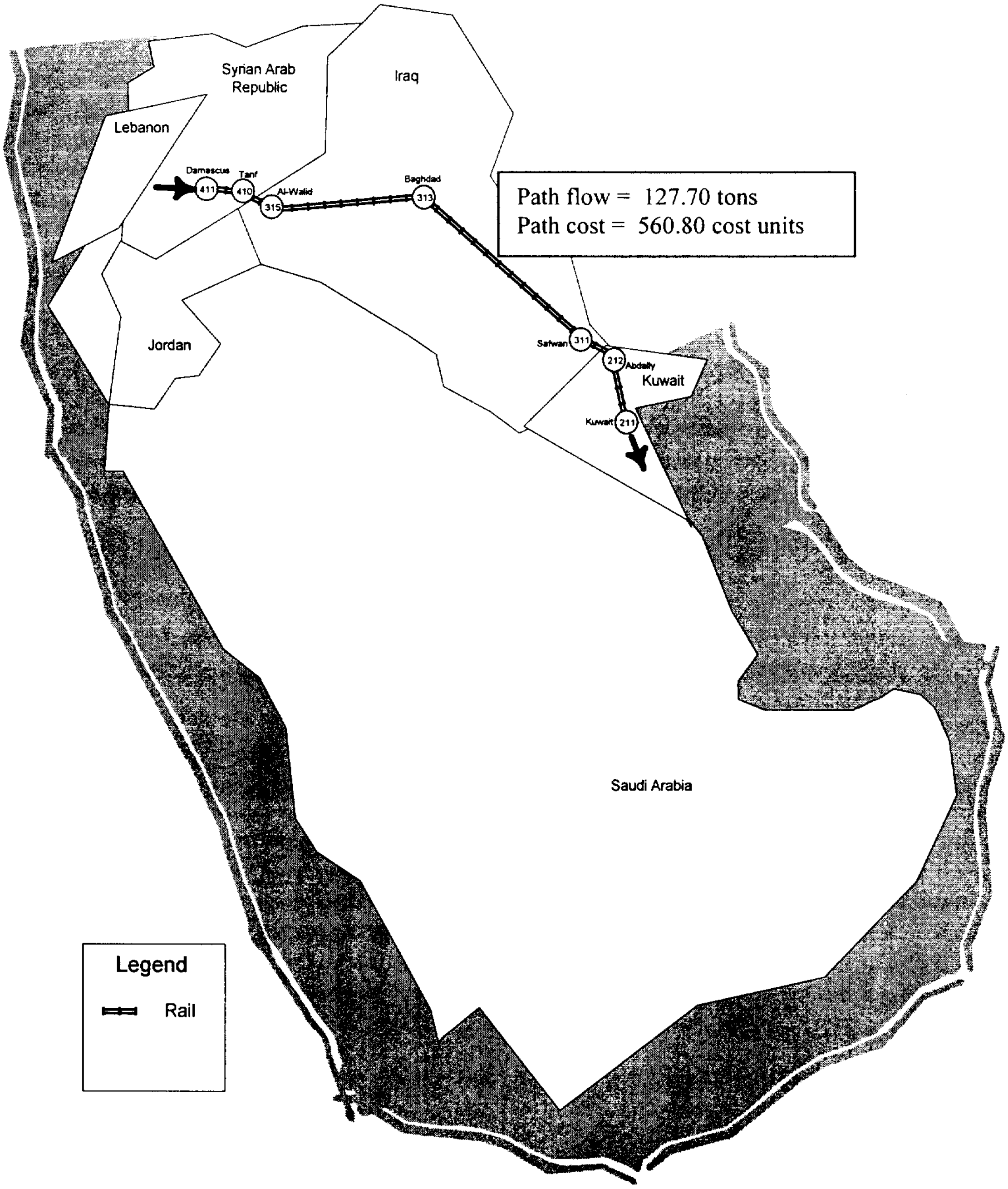


Path 1: Riyadh $\xrightarrow[\text{Rail}]{}$ Jeddah $\xrightarrow[\text{Maritime}]{}$ Beirut

Path 2: Riyadh $\xrightarrow[\text{Rail}]{}$ Hadithah $\xrightarrow[\text{Rail}]{}$ Omari $\xrightarrow[\text{Rail}]{}$ Amman $\xrightarrow[\text{Rail}]{}$ Jaber $\xrightarrow[\text{Rail}]{}$ Nasib $\xrightarrow[\text{Rail}]{}$ Damascus $\xrightarrow[\text{Rail}]{}$ Jdeydet Yabus $\xrightarrow[\text{Rail}]{}$ Masna $\xrightarrow[\text{Rail}]{}$ Beirut

Note: The boundaries shown in this diagram are purely schematic.

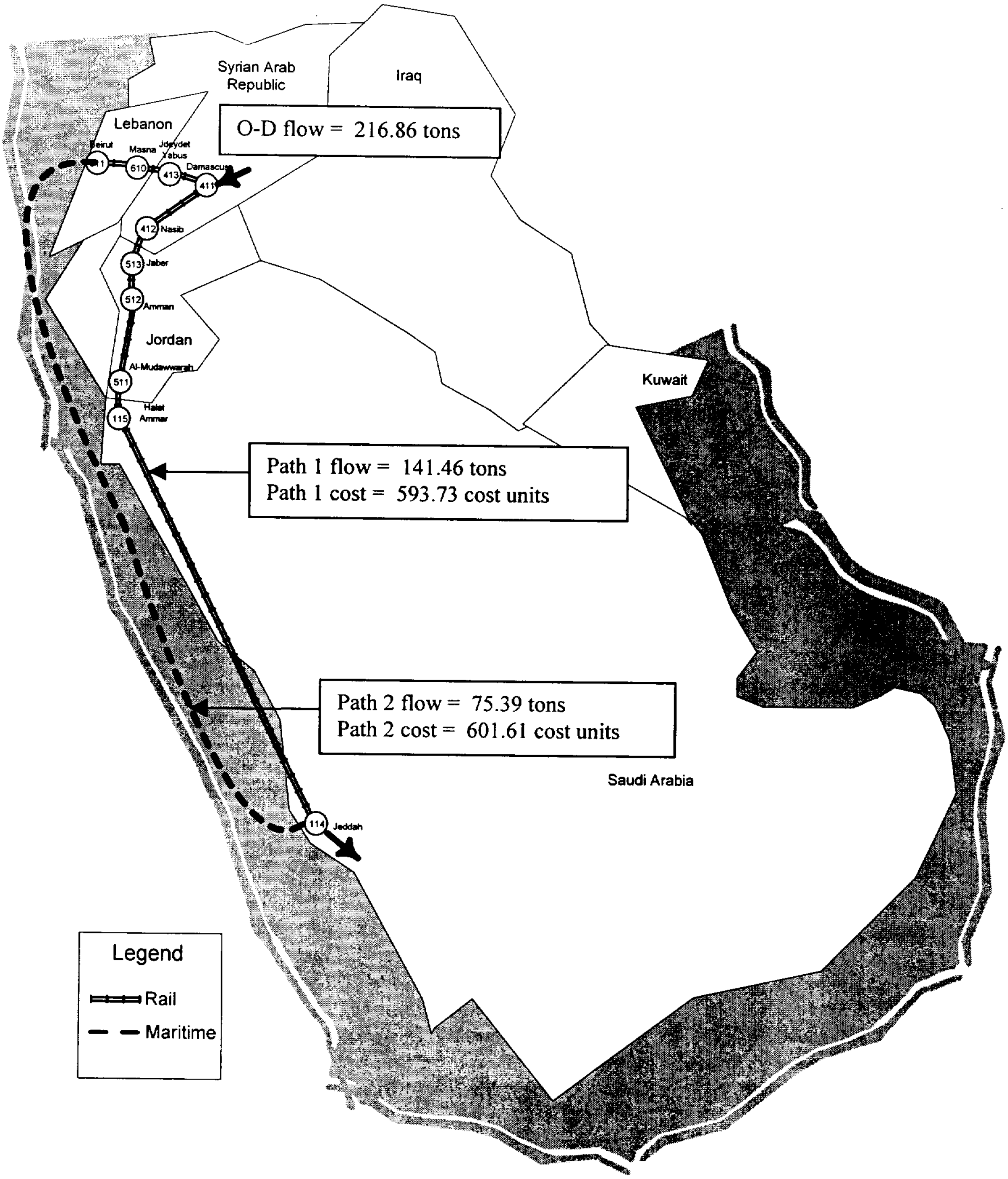
Annex figure XVI. Final solution for Damascus-Kuwait origin-destination pair



Path 1: Damascus $\xrightarrow[rail]{}$ Tanf $\xrightarrow[rail]{}$ Al-Walid $\xrightarrow[rail]{}$ Baghdad $\xrightarrow[rail]{}$ Safwan $\xrightarrow[rail]{}$ Abdali $\xrightarrow[rail]{}$ Kuwait

Note: The boundaries shown in this diagram are purely schematic.

Annex figure XVII. Final solution for Damascus-Jeddah origin-destination pair

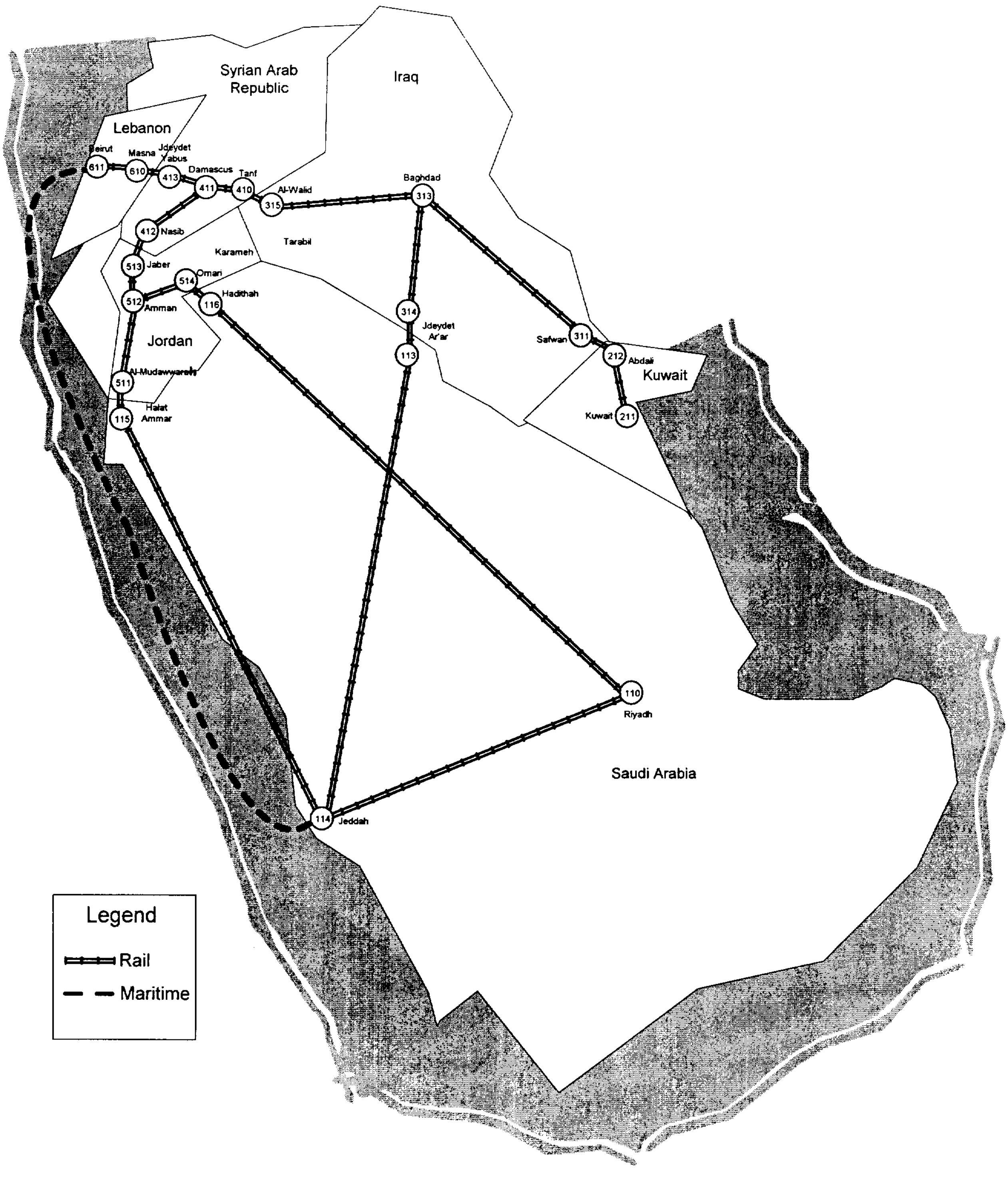


Path 1: Damascus $\xrightarrow[rail]{}$ Nasib $\xrightarrow[rail]{}$ Jaber $\xrightarrow[rail]{}$ Amman $\xrightarrow[rail]{}$ Al-Mudawwarah $\xrightarrow[Rail]{}$ Halat Ammar $\xrightarrow[Rail]{}$ Jeddah

Path 2: Damascus $\xrightarrow[rail]{}$ Jdeydet Yabus $\xrightarrow[rail]{}$ Masna $\xrightarrow[rail]{}$ Beirut $\xrightarrow[Maritime]{}$ Jeddah

Note: The boundaries shown in this diagram are purely schematic.

Annex figure XVIII. Final link flow assignment for the prototype



Note: The boundaries shown in this diagram are purely schematic.

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