DEVELOPMENT OF A DECISION MAKING TOOL FOR FREIGHT TRANSPORT IN THE UAE

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ABSTRACT

The United Arab Emirates (UAE) are a fast developing country with annual growth rates between 5 and 10% for population, economic development and as a result also for transport demand of both passenger and freight transport (at least until the financial crisis).

Currently, the whole freight transport demand in the UAE is accommodated by a road network that had originally been designed for passenger traffic. This has resulted in congestion, delays and external impacts on other road users, the environment and road safety.

The National Transport Authority NTA has now initiated a National Transport Master Plan to develop and test strategies for the future development of the transport system of the UAE. In the framework of this project, a freight transport model has been developed for this rapidly growing area, allowing to model, analyse and describe the impacts of different strategies and measures to improve the transport system particularly the freight transport, like network extensions, development of freight rail systems, transport demand measures and others.

This freight transport model is an important decision making tool and can be valued a landmark for the development of a more efficient freight transport system with less congestion and reduced external impacts.

INTRODUCTION

The UAE National Transport Master Plan was commissioned by the National Transport Authority of the UAE (NTA) in order

- To undertake investigations into the current performance of the strategic transport system serving the UAE
- To analyse transport conditions in future years by forecasting development of demand influencing factors, transport demand and planned infrastructure development
- To develop national transport planning objectives
- To develop strategies, actions and measures to implement these objectives
- To represent different measures and growth assumptions in different scenarios
- And to analyse the internal and external impacts of measures in these scenarios on other transport users, on the environment, on the economic and social development of the country.

A key component of the UAE national transport master plan was the development of a national transport model representing today’s strategic transport system, both supply (network and services) as well as transport demand (passenger and freight), and being able to forecast future transport conditions, resulting from growth of demand influencing factors, like population growth, economic growth, land use development etc. While the development of a passenger transport model was a challenging process in this rapidly growing environment, still it could be based on different existing approaches (i.e. data and models already in place in some of the individual Emirates), the development of a freight transport model was a real landmark process as no freight transport model or approach existed in the area so far.

Freight transport is a by far more complex process than passenger transport; it comprises a number of different freight types or commodities, each having different and special transport requirements and affinities to the different transport modes. And the representation of transport in a model requires by far more data than a passenger model. This is particularly true for a rapidly changing environment as the UAE. Not only is population and economy growing at a very fast pace, but also the economic processes influencing and relying on freight transport evolve quickly over time. Whereas nowadays transport of construction material to the ever changing construction sites dominates freight transport in the UAE, this will look different in 15 or 20 years, when part of the countries infrastructure will have been built and other production processes will become more prominent.

In order to represent the current freight transport system and the future changes to freight transport in a model, an approach has been selected that had previously been successfully applied to countries in Western Europe. However, these countries can be considered somewhat more settled, as here population hardly grows anymore, economy grows slowly and economic processes seem to be more stable. Consequently, this approach had to be adapted to the conditions of a rapidly changing economy. The result is a strategic freight transport model for the whole of the UAE, the first calibrated and validated freight model in the region.

The freight model approach is described in the next section, followed by a section about model applications, i.e. analysing and testing different forecast scenarios.

FREIGHT MODEL APPROACH

Methodology

Commodities

The UAE NTP Freight Model follows a highly disaggregated approach to calculate the freight volumes. Since freight transport as a whole is a very complex and heterogeneous process, it has been divided into different commodities or commodity types for model calculation (see Figure 1)

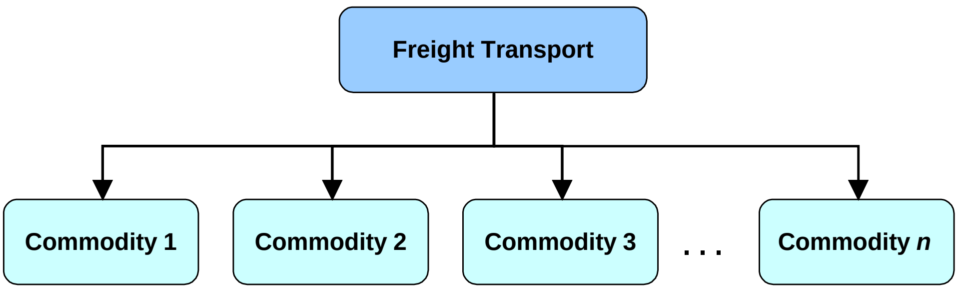

Figure 1: Disaggregation of Freight Transport to Commodities.

The freight model calculation is conducted separately for each commodity. The model covers about 35 different commodities, ranging from agricultural products and foodstuff to construction material, industrial products and consumer goods.

Logistic Systems

The mode and route choice during the assignment step are mainly controlled by the transport costs. Different sets of transport costs are defined for the following logistic systems.

Table 1: Logistic Systems.

Logistic Systems	Description
Bulk Transport	Transport of dry, unpacked goods in large quantities (e.g. gravel)
Container Transport	Transport of goods in containers (e.g. consumer goods)
Food Transport	Transport of perishable goods
Tanker Transport	Transport of liquid bulk (e.g. petroleum products)
Open Heavy Transport	Transport of break bulk
City Delivery (Construction)	Transport of construction materials to construction sites

Commodities with the same characteristics regarding physical conditions and transportability are allocated to one of the logistic systems above.

Transport Modes

The freight model considers all relevant transport modes for freight traffic, except transportation of goods in pipelines, as these volumes do not affect the national road network or future railway lines.

For the Base Year Model the only relevant mode is the road transport, differentiated between heavy goods vehicles (HGV) weighing more than 2.5 tons, and light goods vehicles (LGV). For future scenarios the additional transport modes railway and coastal shipping have been considered to evaluate potential shifts between modes.

Model Components

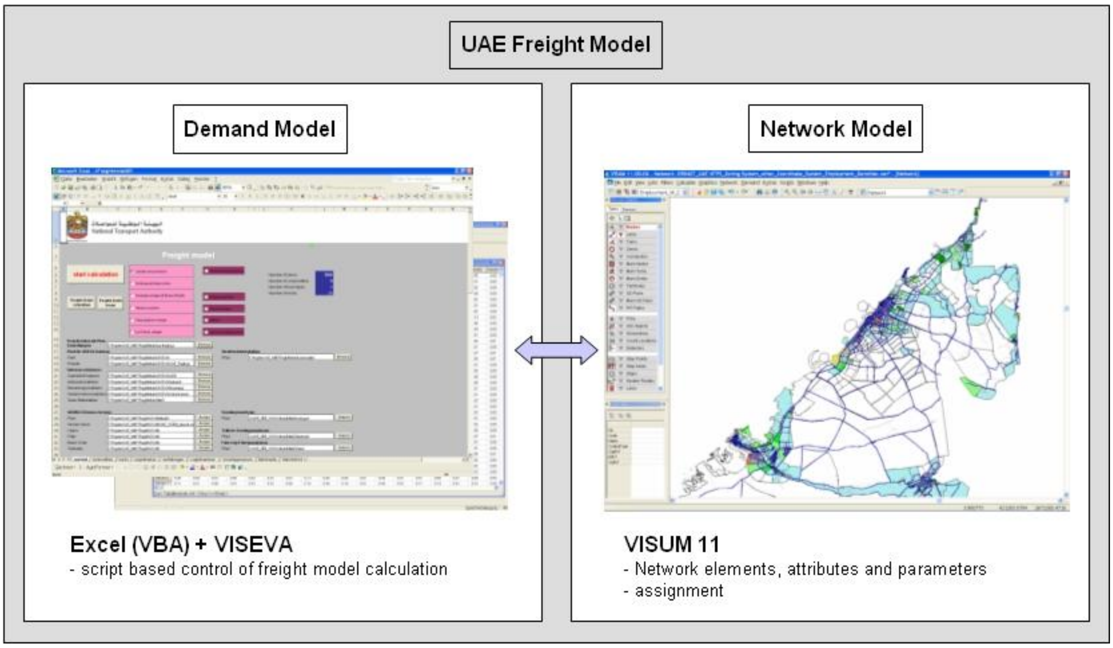

Figure 2: Components of UAE freight model.

The UAE freight model consists of 2 components:

- Demand Model
- Network Model

The demand model calculates ton flow matrices per commodity based on land use data input, network parameters and transport costs. The network model contains all elements of the network supply.

Demand Model

Input Data

As basis for the freight model a comprehensive review and data collection process has been conducted to identify the major freight generators and freight flow patterns. Moreover, the following land use data has been collected as input data for the demand model:

- Differentiated population and employment figures on traffic zone level (having specific consumption rates, e.g. for food products and consumer goods)
- Construction activities (location, construction period and construction volumes of major developments being under construction or proposed for forecast horizon years)
- Agricultural areas with annual output of agricultural products
- Major freight generators such as quarries, factories and refineries and their annual output of goods
- Major transport facilities and hubs such as major ports and airports with their annual volumes of cargo
- Transport costs by transport mode and commodity type
- Import and export data (including location of ports, airports and border crossings as well as the annual import / export volumes by Emirate, commodity and transport mode)
- Forecasts and estimates of future development of population, economy, industry, foreign trade and import / export volumes until the forecast horizon years 2020 and 2030

The data above was gathered from official statistics, previous studies and interviews with stakeholders, including urban planning departments, port and airport authorities, shippers of the private industry sector as well as custom authorities and traffic police.

Calculation Steps

The calculation steps, which are applied in the freight model, are shown in Figure 3. These steps are calculated separately for each commodity to consider their specific characteristics concerning freight generation, distribution, mode choice and assignment.

First, the generated volumes are determined and distributed between the Traffic Analysis Zones (TAZ) as tons per year. After splitting the ton flows to different transport modes like road and railway (the latter is only applied in forecast scenarios), the flows are converted to trips per day or trips per hour respectively. Finally the trips by mode are assigned to the network, resulting in link volumes per day or per hour.

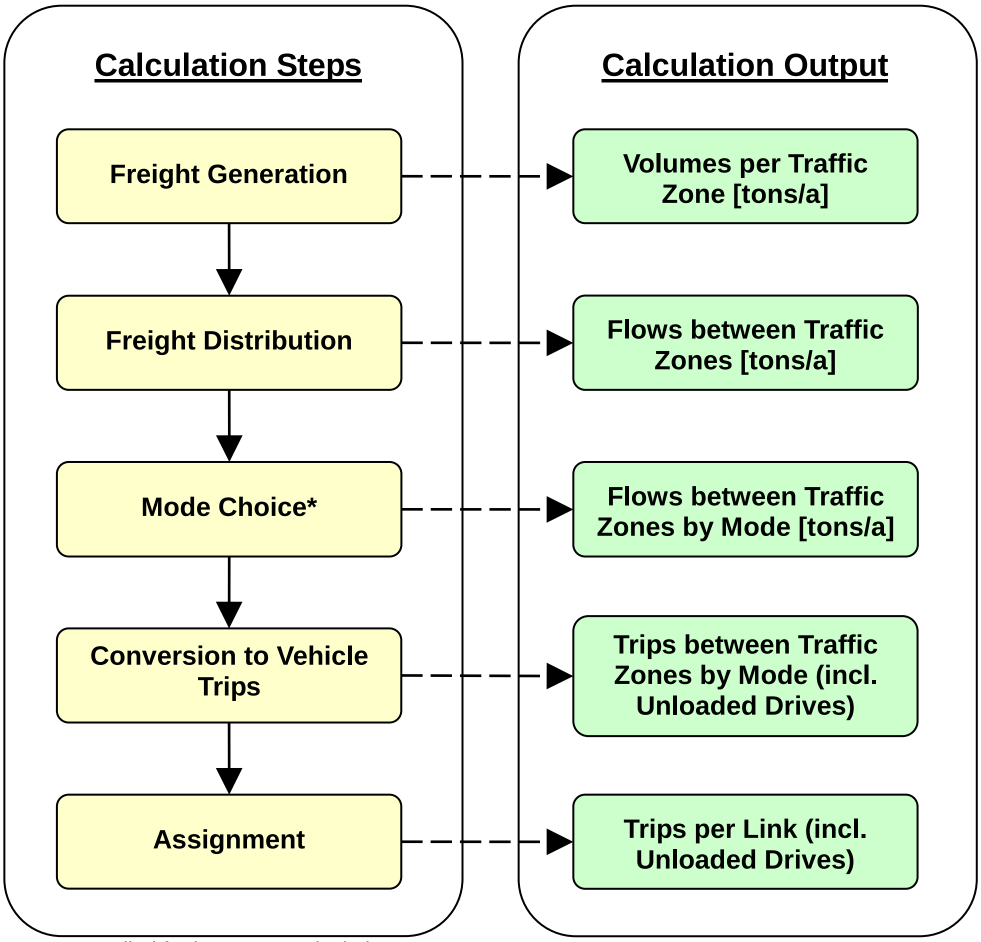

Figure 3: Calculation steps of the UAE NTP freight model.

Freight Generation

As a first step for each commodity, the generated freight volumes by TAZ are calculated as tons per year, both for the origin and destination side. This is based on the constraint, that the total generated volume of all origin zones must be equal to the total generated volume of all destination zones.

While the origin volumes consist of local production volumes and import volumes, destination volumes are the sum of local consumption and export:

$$\sum_i \mathrm{FreightVolumes}_O = \sum_j \mathrm{FreightVolumes}_D$$

$$\sum_i \mathrm{Local\ Production} + \sum_i \mathrm{Import} = \sum_j \mathrm{LocalConsumption} + \sum_j \mathrm{Export}$$

where

O; D	origin; destination
i	index for origin TAZ
j	index for destination TAZ.

The import and export volumes are determined from official UAE import/export statistics. The volumes of local production and consumption are calculated by multiplying the decisive land uses for each commodity with their corresponding production or consumption rates respectively:

$$\sum_{i}(LU_P \cdot R_P) + \sum_{i} Import = \sum_{j}(LU_C \cdot R_C) + \sum_{j} Export$$

where

LU_P	decisive land use for local production
R_P	production rate
LU_C	decisive land use for local consumption
R_P	consumption rate.

Depending on the commodity and on whether the local production or consumption is to be calculated, decisive land uses can be as follows:

- Population
- Work places
- Agricultural areas
- Production facilities
- Construction sites

Hence, by calculating the local production and consumption per TAZ and adding the import/export volumes, for each commodity two vectors are generated. One includes the generated origin volumes per zone, the other vector the generated destination volumes.

Freight Distribution

Like traffic generation, distribution calculation is applied successively and separately for each commodity. Using a gravity model, the generated origin and destination volumes per zone are distributed, resulting in yearly ton flows between the traffic zones.

As gravity model the PTV VISION software VISEVA is used. It is automatically started by the control file and calculates ton flow matrices for each commodity.

Trip distribution calculation is carried out in 2 steps:

1. Calculation of evaluation matrix based on a skim matrix including the impedances between traffic zones
2. Calculation of trip matrix (yearly ton flows) based on the evaluation matrix and the origin and destination volumes

As skim matrices the distance matrix calculated from the VISUM network model is applied.

Mode Choice

General Approach

The mode choice decision for a certain commodity and origin-destination relation is based on the transport costs. Always the most cost efficient route and transport mode is chosen. This can be either a direct transport with one transport system or a multimodal chain with a combination of transport modes and transhipments in between.

For each commodity and O-D relation, the transport mode (or combination of modes) with the lowest total transport costs is chosen by assigning the ton flow matrix to the VISUM network.

Based on this assignment, the ton flow matrix of each commodity is split into ton flow matrices for each transport mode.

Transport Costs

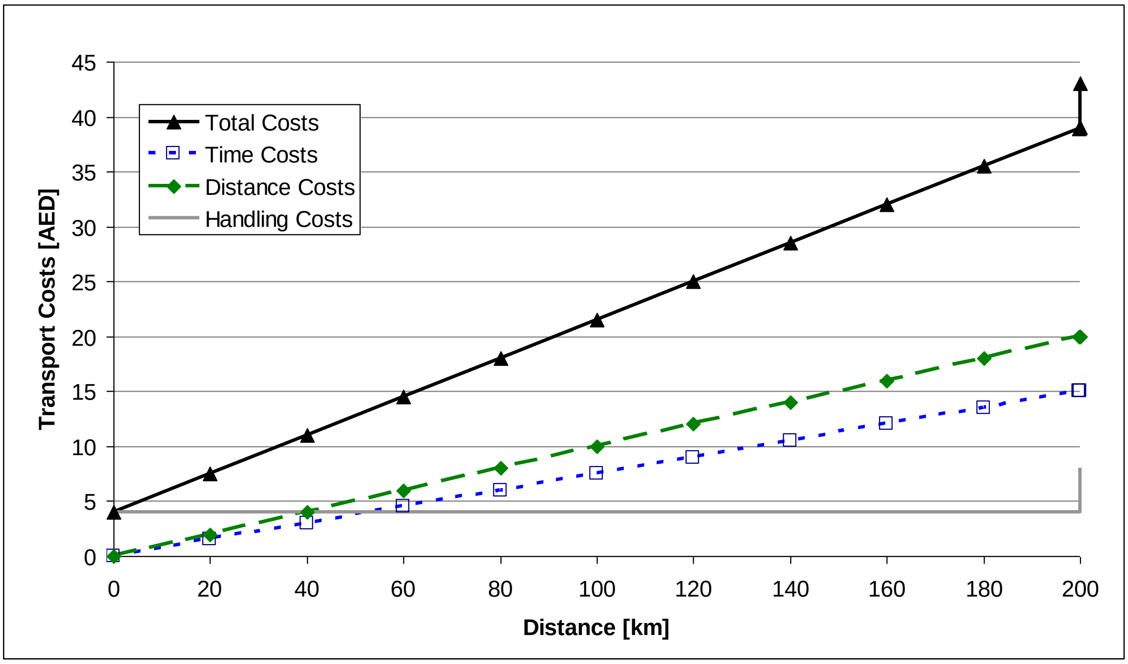

Figure 4: Composition of total transport costs.

As illustrated in Figure 4, the total transport costs, which are the determining factors for the mode choice calculation, consist of:

- Time costs (mode specific time related transport costs)
- Distance costs (mode specific distance related transport costs)
- Handling costs (costs for loading/unloading and transshipment)

As an example, Figure 4 shows the composition of costs for the transport of 1 ton of bulk goods assuming a direct transport on road with an average speed of 80 km/h and a distance of 200 km.

For each logistic system a set of modal transport costs has been defined as input for the following cost function, which has been used for the mode choice calculation.

$$C_{ij}^{r} = \sum_{m} t^{m} * c_{t}^{m} + d^{m} * c_{d}^{m} + T^{m}$$

where

C_{ij}^{r}	costs for a transport from zone i to zone j on route r
m	mode = {road, rail, ship}
t^{m}	transport time (in h) with mode m
c_{t}^{m}	rate per hour for mode m
d^{m}	transport distance (in km) with mode m
c_{d}^{m}	rate per km for mode m
T^{m}	transfer costs per transfer from mode or to mode m

Conversion of Ton Flows to Vehicle Trips

In the first three modelling steps freight volumes were calculated as *tons* per year. For the assignment to the network *trips* per day (or per hour) are required. Consequently, the (modal) ton flows per year need to be converted to vehicle trips.

Therefore, the (modal) ton flow matrix of each commodity is firstly multiplied with an specific average loading factor to convert from yearly tons to yearly vehicle trips and secondly multiplied with a conversion factor to trips per day (or peak hour).

$$[L] = f_L \cdot f_D \cdot [F]$$

where

- $[L]$ trip matrix with trips per day or peak hour (only loaded drives)
- $[F]$ ton flow matrix with tons per year
- f_L average loading factor
- f_D conversion factor to trips per day (or peak hour).

Since the trip matrix does not include unloaded drives, these trips have to be determined and added to the existing matrix. For the calculation of the unloaded trips, the inverse matrix of loaded trips is determined and multiplied with an unloaded drive factor:

$$[U] = f_U \cdot [L]^{-1}$$

$$[T] = [L] + [U]$$

where

- $[U]$ trip matrix with unloaded trips per day or peak hour
- $[L]$ trip matrix with loaded trips per day or peak hour
- $[T]$ trip matrix with trips per day or peak hour (loaded and unloaded trips)
- f_U unloaded drive factor.

As a result, trip matrices per commodity and transport mode have now been calculated including loaded and unloaded drives. Finally, all matrices of one transport mode are added to one total trip matrix per mode.

The conversion to vehicle trips and the calculation of unloaded drives are of importance primarily for the road traffic. The ton flow matrices are converted to separate trip matrices of different vehicle types. For the UAE freight model it has been differentiated between heavy goods vehicles (HGV) and light goods vehicles (LGV). Regarding the split between HGV and LGV, the freight model allows for a differentiated conversion depending on the type of commodity and the transport distance, taking into account that HGVs are predominantly used for longer distances whereas LGVs are mainly used for shorter trips.

The ton flows between traffic zones are converted to single vehicle trips. A consideration of vehicle tours (meaning routes with several consignees) is not subject of this freight model and not relevant for its strategic purpose.

Assignment

The modal trip matrices of each commodity are added to one trip matrix per transport mode, which are then assigned to the VISUM network. For the road traffic there is one matrix for HGVs and one for LGVs, taking differentiated restrictions for heavy vehicles into account.

To consider the interdependences between private road traffic and freight road traffic, the generated trip matrices of the freight model are assigned to the VISUM network together with the private transport matrices. As a result, the freight traffic volumes of links and the percentage of heavy goods vehicles are available.

Network Model

The network model has been built in VISUM 11 and comprises about 1000 traffic analysis zones and both a network for public transport and a network for private and freight traffic.

The transport network model is based on NAVTEQ road network data, which has been revised and complemented with necessary but missing links. For the forecast scenarios, networks of additional modes have been inserted such as a proposed freight rail network and proposed coastal shipping connections.

For the use as a traffic model network a classification of link types was developed from the given base data. Each link type has some defined standard parameters of link attributes. The following table shows the relevant link attributes for each link type.

Table 2: Link Type Attributes.

Attribute	Definition
Number	Number of link type
Name	Name of link type
TSysSet	List of permitted transport systems
NumLanes	Number of lanes
CapPrT	Capacity of private transport within a time interval
v0PrT	Free flow speed of private transport
HGV_Restrictions	Temporal restrictions for HGVs

For the definition of node impedances, both the type of control and the size of the node are taken into account. For the modelling of travel times, volume delay functions differentiated by link type and node type have been used.

Model Calibration

Automatic traffic counts (ATC) and road side interviews had been conducted at major links throughout the UAE to collect data about classified link volumes and travel patterns for the validation and calibration process.

All of the ATC survey locations had been assigned to classified roads, i.e. primary, secondary and tertiary roads. The focus of the validation process was therefore on the classified roads as the statistical representativeness of other road types is generally limited. A comparison for HGV volumes of 24 hour assignment with ATC survey results is presented in the following figure.

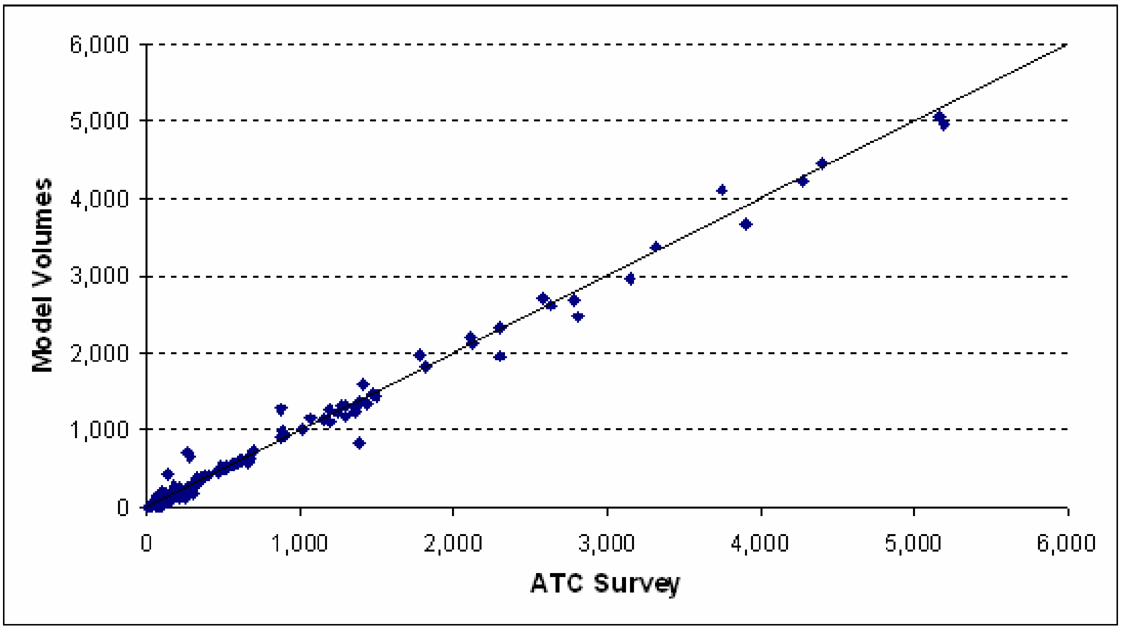

Figure 5: Comparison of ATC Survey and Model Volumes (24 Hours).

FORECAST SCENARIOS AND RESULTS

Forecast Scenarios

The main objective of the UAE National Transport Plan and the transport model was the evaluation of different forecast scenarios, which consider:

- Proposed land use developments
- Proposed network supply and policies

Land Use Data

The future freight traffic demand is mainly driven by the development and distribution of population and employment. Population and economic forecasts have been produced for the UAE and each Emirate with a comprehensive macro economic analysis. As shown in Figure 6, a strong increase of inhabitants and employees is forecasted having a significant impact on the future freight demand.

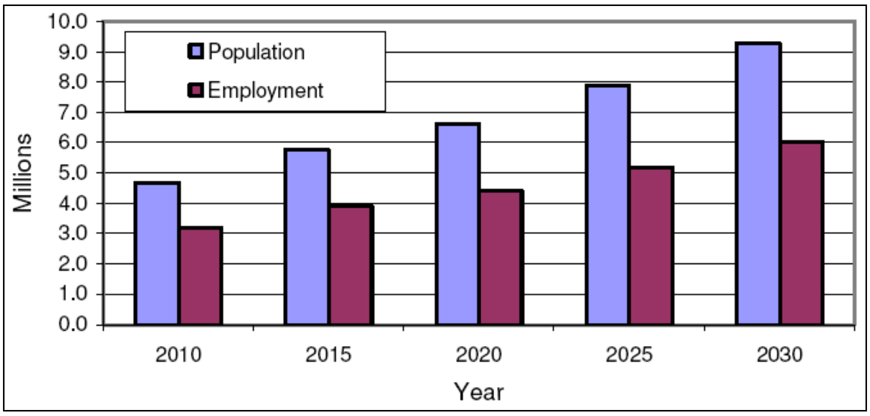

Figure 6: Comparison of ATC Survey and Model Volumes (AM Peak Hour).

In addition to population and economic forecasts, proposed changes in the industrial sector have been considered such as information about location and output of new industrial facilities, as well as assumptions for the construction activities, port extensions and the location of new ports in the future.

Network Supply

Regarding the freight network supply, the following three scenarios have been calculated and analysed:

- A: Do Minimum Scenario
- B: Rail Scenario (Do Minimum Scenario + freight rail)
- C: Rail/Ship Scenario (Rail Scenario + coastal shipping)

The network supply of the Do Minimum Scenario is characterised by road infrastructure measures which are approved or already under construction. These infrastructure measures include new inter-emirate highway connections, special truck routes as well as infrastructure improvements and policies within the cities. Other modes than road traffic are not considered.

The network of the Rail Scenario comprises the same road transport network as the Do Minimum Scenario. In addition, a proposed freight railway network is part of the network supply connecting Saudi Arabia with the UAE and providing freight rail connections also between the cities within the UAE. Furthermore, proposed bulk interchanges and transfer centers are part of the supply, which allow the transshipment of goods between road and rail.

In the Rail/Ship Scenario the road and railway network of the Rail Scenario is extended by additional coastal shipping connections between the Emirates of the UAE. Furthermore additional bulk interchanges and transfer centers for the transshipment of goods to the coastal ships have been considered.

For each scenario forecast calculations for the horizon years 2015, 2020, 2025 and 2030 have been conducted. For this paper the presentation of results will be focused on the time horizon 2030 only.

Forecast Results

The freight model provides information about the generated freight demand for each commodity and calculates the modal share by commodity and in total as well as the resulting volumes on the transport network. Furthermore, it provides information about potential shifts from rail to other modes like railway and / or coastal shipping.

Freight Demand

The demand model calculates generated volumes for each commodity. Due to the increase of population and the economic development a significant increase of freight demand can be expected. Figure 7 compares the demand for aggregated commodity groups between the base year 2008 and the forecast horizon 2030, showing that construction material is the dominant commodity group.

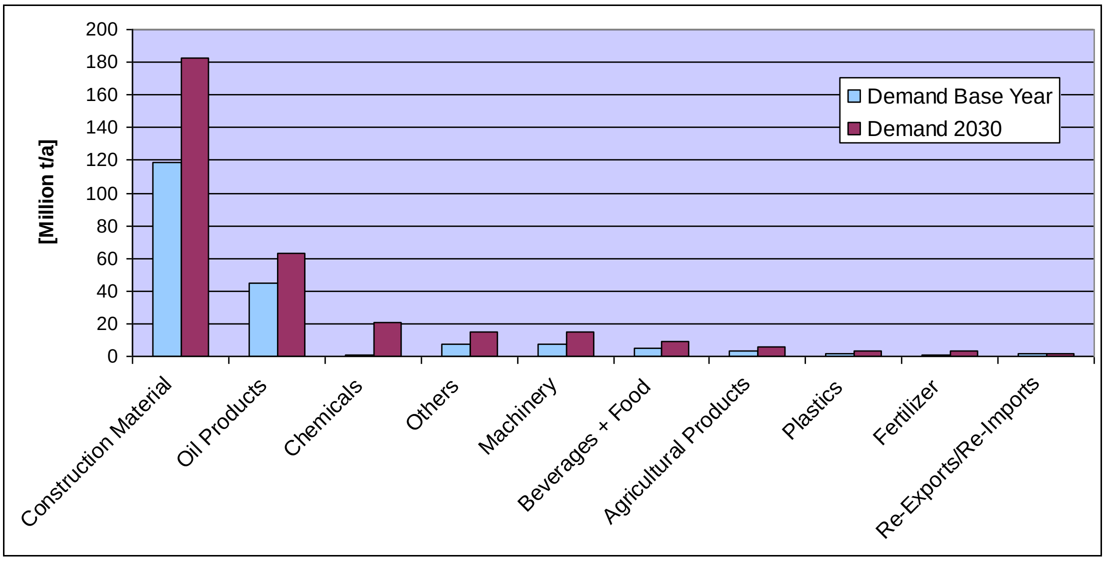

Figure 7: Generated volumes by commodity group comparing base year and 2030.

The generated demand is the same in all network scenarios. Differences can be obtained for the volumes on the network links and modal share of the transport performance (ton kilometres), as described below.

Modal Split

A comparison of the modal split results between base year 2008 and the three 2030 forecast scenarios is provided in Figure 8. A substantial shift from road to the proposed freight railway and / or the coastal shipping connections can be observed.

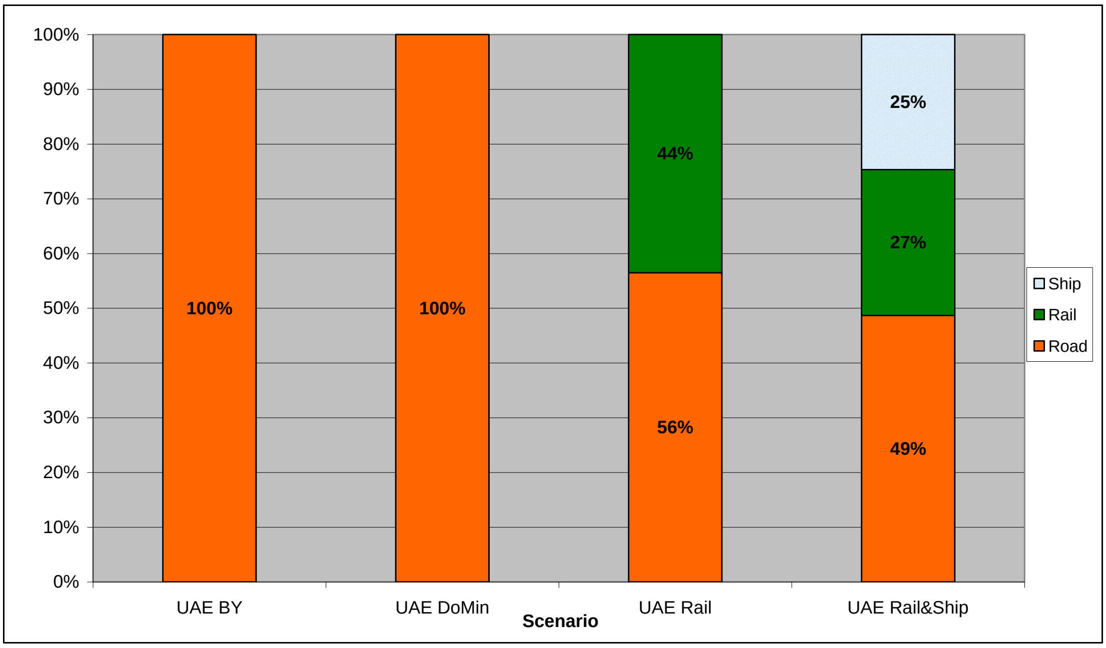

Figure 8: Modal split of ton kilometres for base year and 2030 freight scenarios.

A more differentiated analysis of the modal split is shown in Figure 9 providing the modal share for aggregated commodity groups. As can be seen, especially bulk goods are shifted from road to alternative transport modes, whereas perishable goods and high-value goods are predominantly transported by road.

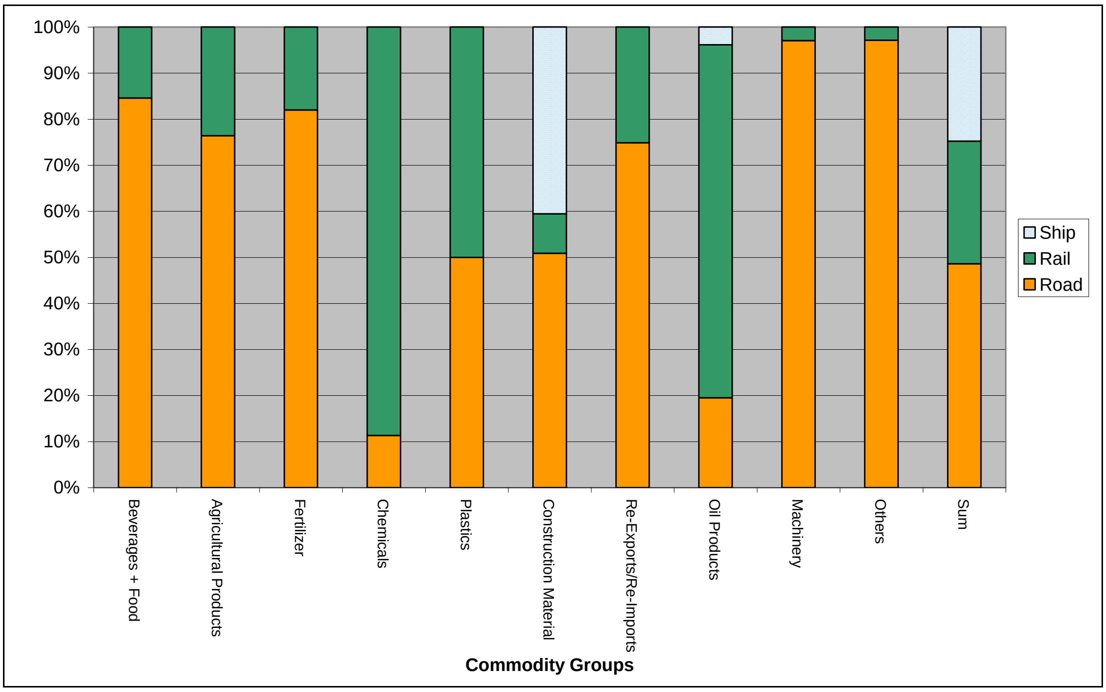

Figure 9: Model split of ton kilometres by commodity groups – Rail/Ship Scenario 2030.

Freight Volumes and Modal Shifts

Evaluating the resulting volumes on the network links, a significant reduction of road traffic can be noticed by introducing a freight railway network and / or coastal shipping connections. Figure 10 shows a difference network between 2030 Do Minimum Scenario and 2030 Rail/Ship

Scenario. Especially along the north-south corridor, where the proposed freight railway runs in parallel to the highway connections, a substantial shift from road to rail can be observed.

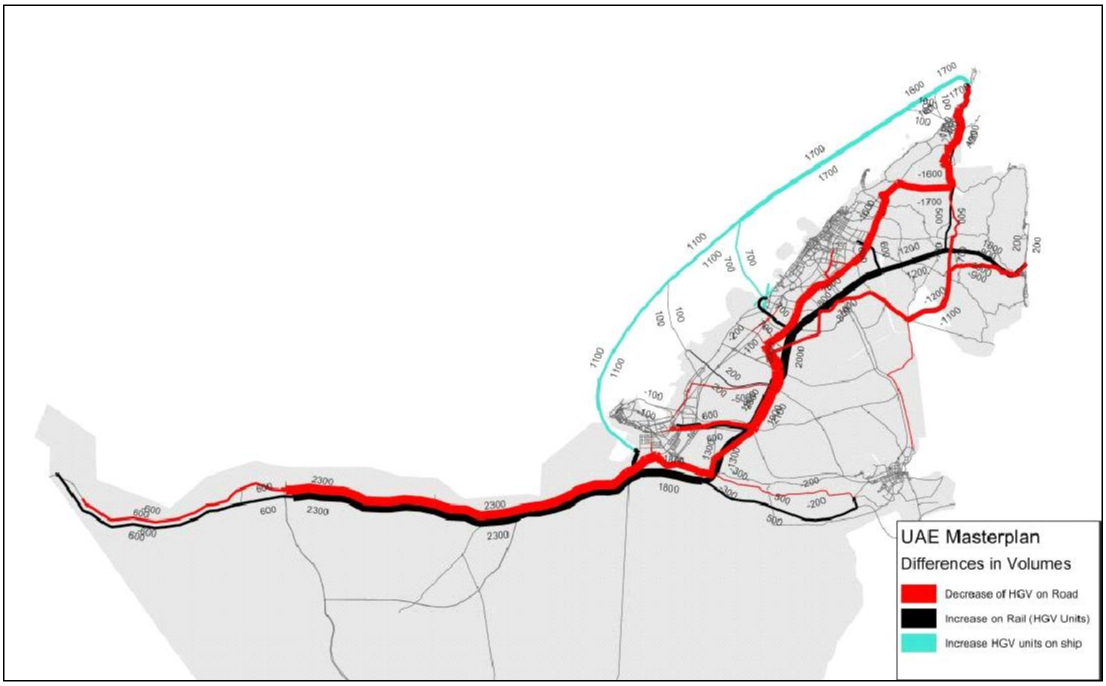

Figure 10: Difference network 2030 Do Min – Rail/Ship Scenario; shift from road to rail and ship.

CONCLUSION

The development of objectives for the development of a future transport system for the UAE and the determination of strategies, actions and measures to implement these objectives require a tool to analyse the effects and impacts of the relative measures. This tool is usually a transport model allowing to calculate transport volumes, travel speeds, emissions etc. Consequently a transport model had been designed and implemented for passenger and freight transport in the UAE, including a base year model for 2008 and forecast scenarios up to 2030. Both, the passenger model and the freight model had successfully been calibrated and validated with extensive empirical data for the base year.

Especially the freight transport model described in this paper can be considered as a landmark development as it is the first freight transport model in the region, describes the underlying processes with high level of detail and represents current conditions satisfactorily.

The National Transport Master Plan has therefore provided decision makers and stakeholders in the UAE with a powerful decision support tool in form of a strategic national transport model that can be used for all transport planning decisions now and in future. As described in this paper, the model had already been applied to the selection and analysis of different forecast scenarios for the process of developing a future transport strategy for the UAE.

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AUTHOR BIOGRAPHIES

Dr Uwe Reiter joined PTV AG 12 years ago. He is the Director for International Consultancy and Head of the Berlin Branch of PTV. At PTV, he was responsible and has worked on numerous projects in the fields of transport planning, traffic engineering, transport telematics, transport management and mass transit/ public transport. He has developed general transport master plans, public transport master plans as well as transport management systems, systems for traffic control and operation for cities and regions of different sizes. He was the Project Manager for the Transport Master Plan for Qatar and was based in Doha for the duration of the project. He was the project director for the PTV contribution of the UAE master plan.

He has a background in transport planning, in transport modelling, in transport management, telematics and traffic control based on many years of practical experience, academic research and university teaching. He has considerable international working experience. Before joining PTV, Dr Reiter worked as Rees Jeffrey's lecturer in Transport and Environment at Imperial College London (University of London), where he developed his own teaching and research programme in transport and the environment. This included environmental impacts as well as land-use transport interaction.

Dr Reiter received his Ph.D. at the department of Civil Engineering at Karlsruhe University in Germany. Prior to this, he had studied Computer Science at the same University, receiving the Master Degree in Informatics. Dr Reiter is currently Member of the Editorial Advisory Board of Transportation Research Part D – Transport and Environment.

Jens Landmann graduated from the University of Technology Dresden with a Diploma in Civil Engineering with emphasis on Theory of Transportation Planning, Spatial and Infrastructure Planning, Traffic Engineering, Design of Roads and Railway Lines and Road Safety.

Between 2002 and 2005 he joined PTV during his studies as an intern at PTV's branch in Dresden, Germany and PTV France in Strasbourg where he was involved in traffic studies and demand models, e.g. the research project MOSCA, demand models for the cities of Chemnitz (D), Leipzig (D) and Lille (F). Additionally he contributed to the research project within INTERREG 3b.

In 2007 Jens joined PTV as a Project Engineer in the International Consulting Planning Projects Department. He gathered extensive and wide-spread experience in international projects such as: Transport Master Plan for Qatar 2007, Long term Demand Forecasting 2025 for the region of Berlin/Brandenburg 2008 (D), Qatar Integrated Railways Project (2008), Belgrade Waterfront Development 2008 (Serbia), the UAE National Transport Plan 2009 and the EU funded TRACECA – IDEA project, the transport dialogue and interoperability between the EU and its neighbouring countries (Transport Corridor Europe-Caucasus-Asia) 2009-2012.