3D Hierarchical Road Network

Mega-cities feature many complicated 3D-transportation structures such as flyovers, tunnels, ramps and viaducts. As urban spaces continue to burgeon upward and down-ward, modern road-network systems grow in multidimensionality and dynamism while the traffic-control systems of many are executed at lane level. Examples are turning restrictions, speed limits, one-way instructions, limited width, emergency and movable lanes, such as bridges. Yet these roads are still represented as two-dimensional data.

Limitations
Indeed, over the past twenty years road networks have been commonly modelled as 2D centrelines, simplifying the complicated transportation system to a network of single lines and treating flyovers as points. Such 2D-models suffice for macro-transport applications at city/provincial level, but do not satisfy the needs of large-scale applications in urban settings. For example, fire brigades may be wrongly navigated to the emergency site because of a missing lane change, or a heavy fire-engine may be unable to negotiate a certain segment of road because a centreline-based map fails to warn that its width is subject to 2m restriction. The need for change from street-based level into 3D/lane-based is compelling and requires innovation.

3D Data Capture
The swift development of GI technologies, especially GIS, has promoted the combined use of GIS in the transport sector. This has brought to birth a new and booming subject called GIS-T. Three-dimensional road capture can now be highly accurately done by many methods, including Terrestrial Laser Scanning TLS and DGPS (Differential GPS), while 3D-data management, 3D-representation and 3D-analysis have been greatly enhanced by research into 3D-GIS and Virtual Geographic Environments (VGE). So that existing GI technologies practically enable the comprehensive description of road networks in their full three spatial dimensions.

3D Road Network
Some lane-based and 3D-road network models have recently become subject to intensive discussion within the GIS domain. The strengths of such models are the possibilities they offer for:
-visualising 3D structures such as overpasses and on-ramps, and 3D operations such as distance measurement
-defining detailed traffic-flow characteristics such as bus and emergency lanes, and traffic rules such as lane changing, and speed
-relating 3D-geometric information to each lane: 3D objects presented in 2D in GIS may lose properties such as texture, graphic, height, and their spatial relationships to other objects.
Living in a 3D-environment does not mean to say that we should abandon the 2D-roadway, centreline-based, network model and from now on only do lane/3D-based modelling.

Hierarchy
We face a changing world, complicated and vulnerable to sudden disorder. Fast evacuation of people from ‘emergency areas’ after terror attack, earthquake, flood and other heavy-impact catastrophe requires representation of the 3D-world at many different scales. Hierarchical data structures are an answer to this need, and crucial for support of all scales of navigation implementation in the transport sector is a sound hierarchical road network model. Hierarchical data structures provide flexible, natural and rational means for problem solving, at different levels of detail (LODs). Based on recent achievements, the following is a three-level hierarchical road network model:

-Level 1: Road centrelines provide macro-scale representation by depicting the general configuration of roads as single lines and complicated flyovers as nodes. They are aggregated into streets with either one or two directions of flow. Applications include 2D-transportation planning, street naming and digital mapping.

-Level 2: A collection of lanes with the same (in most cases) or different directions of flow, without dividing strips or a double-line divider between the lanes. In such a carriageway-based network model a flyover is depicted as a series of links; it may thus serve for meso-scale 2.5D applications such as trajectory-data and traffic-flow analysis.

-Level 3: Micro-scale representation in which each line depicts one direction of flow to reflect vehicle movement at lane level. Such a lane-based network model reflects real 3D-traffic rules and user-oriented navigation behaviour.

X-GDF
International organisations are attempting to advance the existing Geographic Data Files (GDF) standard tobetter support safety applications such as indoor/outdoor evacuation in a 3D-environment. Hierarchical navigation modelling will become an integral part of the ongoing standard X-GDF, the next generation GDF developed by ISO/TC211. The use of the hierarchical road-network model will support more advanced routing and navigation strategies, such as hierarchical routing and multi-modal navigation. It will also improve the computation efficiency and scenario representation involved in 3D-navigation during evacuation efforts.