# Layer-based Data Structure for Integrated Transportation System

Nguyen Thanh Hung[1], Zin Lin [2], Hideto Ikeda[1] and Nikolaos Vogiatzis [3]
[1] Department of Computer Science, Ritsumeikan University, Japan
[2] Department of Signal and Telecommunication, Myanma Railway, Myanma.
[3] Transport System Centre, University of South Australia, Australia

## 1 Introduction

Current transportation systems are gradually becoming more and more integrated in relation to activities such as public transport scheduling, recommending alternative mode choices and shared ticketing technologies; however the current level of 'cooperation' is not sufficient if one is interested in coordinating activities associated with human or natural disasters such as terrorist attacks, or earthquakes, or tsunami. In order for this to occur, it is imperative that numerous organisations cooperate more closely.

The notion of integrated transportation systems (IntegTS) as proposed by Ikeda and Vogiatzis and their colleagues [1,2] is an attempt to find a solution to the way in which one can coordinate disparate organisations through their information systems infrastructure. Underlying IntegTS is the intention to integrate various transport-oriented information systems into one overarching system to improve efficiency, flexibility and safety of transport related activities. The base design of the new system uses the Three Layer Object Model (3LOM) which consists of managing 'front-end' components, database management and knowledge management. IntegTS as a system is a very large-scale information system and it is expected that once operational a wide range of organisations will be interested in joining and contributing to the system. As such, it is important that the final design and implementation of the system should be done with great care and in coordination with all the major governmental organisations as errors and system failures have the potential to affect society as a whole.

This paper proposes a design policy and physical data structure of the database system to be implemented in the IntegTS. There are currently some proposals for data models for transportation management; however, those data management systems focus on specific purposes/issues, such as an extending transportation planning models [3], or an on-road driving database [4]. The most important requirement for the model is how to maintain the stability of the target transportation system and recommend the best alternatives in the case of emergencies. The paper describes the layered design of IntegTS that consists of a general map, a general transportation system, a schedule based transportation system, a non-schedule based transportation system, and a railway transportation system.

## 2 Motivation

### 2.1 Integrated Transportation System

Ikeda [2] proposed a system configuration model (3LOM) for IntegTS as follows;

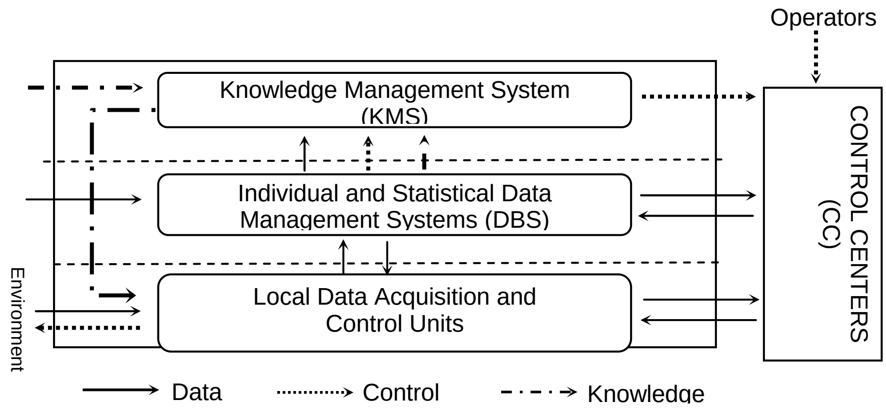


Figure 1: 3LOM architecture of Integrated Transportation System

In Figure 1, the three layers of the system-3LOM include local units in the bottom layer, individual and Statistical Data Systems (DBS) in the middle layer and a Knowledgebase System (KS) in the top layer and an independent Central Control system (CCs) for manual/human control. The lowest layer manages specific controllers located at intersections, acquires data from those locations and controls the environment. Data are acquired by a local unit known as front-end components and transmitted to the data management system or related to control centres. Some data are used specifically for the control in individual locations whereas other data are locally summarized and transmitted to the middle layer. As a front-end component, a REP terminal provides functionality for sending and receiving information between the vehicle and the control centre. The DBS in the middle layer also manages data from individual controller and system-wide data for the purpose of resource management, analysis and transport facilities planning. The data in the middle layer are used for establishing new knowledge rules, supporting the activities of departmental transport authorities, registration of vehicles, and administration of roads. In the top layer, KMS manages the control/behavioural rules associated with the environment such as intersections, facilities and appropriate rules for conditions whereby one needs to coordinate accident wardens, and traffic congestion. Finally, control centres are established for the specific purpose coordinating fire control, highway monitoring, road traffic monitoring etc. Each control centre connects related local units (such as intersection controllers, etc) to get appropriate data for its control.

Thus, the IntegTS covers a very large area and includes many different organizations that share data of the proposed system. The benefits of the system are numerous, but primarily are 1) efficient data transmission among major system components such as traffic control, traffic network users, and traffic network planners/analysts. 2) Improvement of efficiencies in traffic flow management. 3) Increase of safety for all network users. 4) Improvement of route setting for network users. 5) Improvement of intelligent traffic management and self-learning through experiences. 6) Reduction of traffic law infringement, and 7) enhancement of “what-if” scenario planning/ modelling.

## 2.2 Requirements of Data management system for the IntegTS

Based on the discussion above, we consider the requirements for the implementation of IntegTS. Collecting data is only the first step, the system requires the architecture to support the storing, management, retrieval, and manipulation of data and is the major contributing factor for the success of the system as such the requirements are:

1) Storing and management of the resource data of transportation systems (e.g. facilities data, geographic data, schedule data, departmental data etc);
2) Updating real time data from probe cars for individual users;
3) Efficient use of resources; and
4) Viewing user information in the database.

### 2.3 Role of Database design for Transportation System

Basically, there are four types of resources: physical resources, human resources, financial resources and information resources. Typically, transportation systems in general utilize a considerable amount of these resources and therefore, transportation resource management systems play a crucial role for improvement of safety, efficiency and effectiveness. The key performance criteria of these systems must support the maintenance, sharing, planning and analysis of the resources that are relevant with any transportation system. Moreover, there are many different transport activities, such as driver activities, and vehicle movement and, therefore, recording and retrieving the information associated with those activities assists with the analysis of transportation system performance (such as intersection, link and network performance, network reliability and more), planning for future activities and controlling real time transport operations and so on. In order to achieve a well-managed environment and control of the transport leviathan, a well-organized information system is essential particularly for the development of a new type of transport control system.

From the database point of view, a database is buttress for any kind of information system. There are many different kinds of database management systems; the current representative database systems are relational database systems, object-oriented database systems, object-relational database systems, distributed database systems, historical/ temporary database systems, real-memory database systems, multi media database systems, statistical database systems, data warehouses, knowledge base systems, XML database systems, and streaming database system. Each of these systems includes have unique capabilities that satisfy some specified requirement/s and can be used in numerous applications. By using such database systems, basically, all data can be shared by two or more organizations. For example, the Nexus II database (which uses a distributed database middleware on top of an object-relational database management system) which has been designed for multiple organizations to be able to analyse SCATS (Sydney Coordinated Adaptive Traffic System) data [7]. Our aim is to integrate the different types of existing transportation related information systems and therefore, we need to consider how to integrate data structures from these systems. Thus the analysis of existing transport information systems, and also for example geographically separated transport systems (i.e. the transport system in Kyoto, Japan as opposed to Adelaide, Australia) is essential to implement the data structure for integration. On the other hand, the data structure must avoid unnecessary data redundancies, data structure redundancies and operational redundancies. Thus, we need to reorganize the database in order to control the data redundancy and data structure redundancy properly.

## 3 Four-layer database model for the Integrated Transportation System

### 3.1 Existing different types of transportation system

Generally, transportation systems are classified into four types: road, rail, water and air transport. Moreover, different types of transport systems can be classified into other ways, such as public and private transport, passenger and cargo transport. In fact, among the above general classifications, there are many specific types of transport system such as, helicopter, taxi, bus, ship, airplane, private automobile, and passenger train.

### 3.2 Geographic Information Systems and Transportation Systems

It is evident that geographic information system (GIS), nowadays, is very important in our society. GIS is not only used in the management of transportation systems but also used in military operations, disaster mitigation, etc. However, our focus is transportation system management and therefore, we will analyse the requirements of GIS for transportation systems. Giving the necessary geographic information to transport related persons, can improve the safety and efficiency of the system. Requirements for geographic information are not only useful for identifying routes and the stop points but also for transport related information such as fire stations, hospitals, etc. Moreover, climatic information for specific locations is also very important to improve the safety and efficiency of transportation systems[6].

## 3.3 Implementation approach for Integration different types of Transportation system

### 3.3.1 Collaborating between organizations

In accordance with the existence of various types of transportation systems, one approach is that of linking databases for each of the systems for the sharing of data. In this approach, all transport organizations must have their own database and software programs to manipulate the information ultimately this approach has introduced a high level of redundant data, data structures and operation.

Concerning data redundancy, some transport modes may share specific infrastructure; i.e. public transport groups including public bus operators, taxi operators, private vehicle users, etc all, naturally, use the road network and its associated infrastructure. In the case of 'linked' databases, each of these entities will need to replicate that aspect of the database and collect similar data. As such, it is possible to see how suddenly we have a great deal of redundant data in each 'database'.

The second disadvantage is data structure redundancy. Some of the functions of different types of transport systems are similar. For example, the processes of scheduling for most of the public transit system such as bus scheduling, train scheduling, flight scheduling are similar. Therefore, data structures for those functions can be shared among different transport organizations. If the databases are scattered, then programs or components cannot share the data structure and we need to develop different programs with similar functionality.

Concerning operational redundancy, as each database is different, so each organization needs to manage their relevant databases containing the same information such as, road information for bus and taxi databases.

However, there are situations where it is not possible to share data; privacy concerns for customers of transport must at all costs be preserved. That is, personal information, behavioural information and more must be protected and thus organizations may be required to ensure that any information provided can not be accessed by third parties. An excellent example of this is regional transport authorities where each jurisdiction is required to maintain private information however this information for reasons of probity can not be made available in any way outside of the confines of the organisation that has collected it.

### 3.3.2 The necessary data structure for the Integrated Transportation System

In order to avoid the redundancies previously mentioned, the approach to designing the IntegTS database will include the analysis of the necessary data structures for transportation systems. We take into consideration the weather and geographic information first. Generally, geographic data are related with spatial data or mesh data and transport routes such as arterial road geometries, freight route links, and logistics sinks/sources, just to name a few. Transportation control needs climatic information for specific transport locations e.g., intersections and bus stops. Although this sort of data is different from typical transport data, they are necessary for integration as it is possible that weather may have an impact on the decisions of network users. However, weather data is generally, at this stage, available for each and every location in an urban environment, for example. Typically weather data is collected at weather stations and this data is made available for large regions. The inclusion of 'mini' weather stations at intersections has a two-fold advantage; 1) it allows for the use of weather as a contributing factor of transport, and 2) it can feed into meteorological systems used for weather prediction. Also, road data must include spatial information as along with intersection/link geometry and so on within geographic databases and also needs to include transport related data, such as permitted vehicle types and speed limits in a transportation database. Therefore both data structures must be associated with one another to facilitate the above requirements.

In order to get the detailed information of a specific aspect of the transportation system, it is essential to design a detailed data structure. However, the usage of some resource types is distributed among the different transport modes, for example, roads are used by public buses, motorcycles, taxis, etc and some of the devices that are equipped at railway level crossings are utilized by rail and road networks. Moreover, if we analyse the other transport routes such as, rail corridors, sea-lanes, air lanes, all have similar basic properties, such as, length, width, etc. Therefore, those kinds of objects can be integrated into one entity to avoid unnecessary data redundancy in a transport database. Along with the above analysis, other similar transport related entities can also be integrated and, therefore, the design of an integrated transportation data structure is necessary for the collection of common data for the different types of transportation systems. It should be noted, however, at this stage we have not taken into account legislative requirements, for example, typically a train control system is **not** integrated with the traffic control system as there are issues and concerns with relation to rail safety (e.g. in Australia we have: South Australian Rail Safety Act 1996 (as amended) New South Wales Rail Safety Act 2002 (as amended), Victorian Rail Safety Act 2006 (as amended); in Canada, the Railway Safety Act (1985, c.32 ($4^{th}$ Supp.)), and in Ireland , No. 31 of 2005: Railway Safety Act 2005 (as amended)). This is a primary concern of transport system integration, however the manner in which these systems will be integrated can and will take into account the necessary concerns and traditional boundaries with each of the transport sectors of interest without reducing the efficiency of the proposed solution.

Traffic congestion is becoming an ever-increasing problem [1]. It seriously impacts the efficiency and effectiveness of transport. In order to improve road traffic congestion, one must consider the currently applicable traffic control algorithms such as signal timing, rules, and regulations. In adaptive traffic signals control systems signal timings are altered by passenger vehicle volumes and freight volumes (i.e. traffic flow volumes), etc. Among many factors of importance when considering the management of transport systems (including policy, economic, the relationships between transport network users and managers, etc) [6], traffic flow volume is very important for controlling road transport as traffic flow volumes can be directly used for real time control, such as changing signal timings (based on typical criteria such as gap acceptance, intersection demand/capacity, geometric delay and queue lengths, just to name a few, and for future planning, such as the construction or redesign of a road. In fact, traffic volumes can be altered based on two key criteria, the operation of 'fixed' vehicle operators (e.g., bus) and dynamic schedule vehicles (e.g., taxis, passenger vehilces). Therefore, traffic volume can be classified in two ways as predictable and unpredictable volumes; this is because entities such as buses are running based on fixed schedules and, entities such as taxis, private vehicle can 'choose' when and where they wish to go. Other transport modes, such as urban light/heavy-freight rail, aircraft, etc also function within the constraints of a fixed schedules and a generally fixed path. Moreover, the common characteristic of those modes is that all the schedule based vehicle operations must follow the instructions of their 'controlling' organization. Therefore, one could suggest that the individual driver has no right to change the course or timetable of trip, at least not without first confirming the change or based on network conditions. If we consider this from the data structure point of view for schedule based transportation modes, although data might be different, the data structure can be shared among different organizations.  On the other hand, the characteristic of transport modes such as taxis, private vehicles, motorcycles, are different with relation to schedule based transportation system because, although they have individual schedules, individual persons can change the course and time of vehicle operations. Therefore, those kinds of transport modes can be referred to as non-schedule based transport modes. The data structure of those systems must be separated in order to support the temporary schedule of vehicle operation.

3.3.3 Layer approach for Integration of different types of transportation

In order to design the transport data structure, we analyse some entities. Our results suggest that some specific transport entities may inherit their properties from other entities within an integrated transportation data structure. As an example, a rail car is a kind of transport vehicle. In order to express the detailed properties of a rail car, this entity must be included within a railway transport data structure; however, any common information relating to the vehicle type/mode must be included in the integrated transportation data structure. Therefore, we can say that rail car inherits from the transport vehicle group; nonetheless, in accordance with the level of detail point of view, rail car is more detailed than transport vehicle.

In order to facilitate the reduction of data redundancies, data structure redundancies and operational redundancies, we propose a layer structure to the design of the system data structure. Currently, we have defined some of this structure using existing technologies, such as object-oriented design, telecommunications and web-design; however, the significance of a layered structure in this research is to classify common information and specific information for the integration of transportation modes.

## 3.4 Four-Layer database Model

3.4.1 Architecture design

IntegTS data structure is proposed by a four-layer database model shown in figure 2.

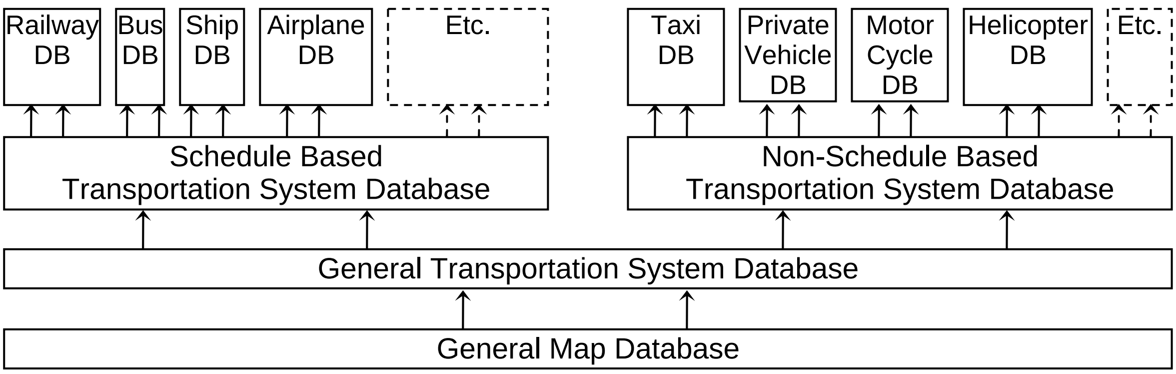


Figure 2: Architecture design of Four-layer database model

The lowest layer manages geographic and climatic information relating to the transportation environment. This layer's name is the 'General Map Database' (GMD) as the data structure will contain geo-spatial data.

The primary middle layer is named the 'General Transportation System Database' (GTD) and manages common information for general transportation mode/entity. Some entities might have vertical relationship with the entities in the general map database as it is possible that the entities may have geo-spatial elements.

The secondary middle layer is separated into two data structures namely a 'Schedule Based Transportation System Database' (SBTD) and a 'Non-Schedule Based Transportation

System Database' (NSBTD). The SBTD data structure is for the transportation modes for which vehicle operations are based on a fixed schedule and NSBTD data structure is for transport modes in which vehicle operations have no schedule component.

The top layer is used to manage specific transportation mode data and structured in order to record detailed mode performance information.

### 3.4.2 Physical design of the Layer database Model

Figure 3 shows the physical structure of the four-layer database for transport. Some common tables are represented in all layers and the level of detail can be classified by the assigning of specific attributes. Geographic and climatic information are assigned in the lowest layer and therefore, some tables might not specifically be related to the transportation data structure. With relation to specific modes, the common tables are located in GTD layer to support general information for any kind of transport mode. The classification of SBTD and NSBTD is expressed in the secondary middle layer and some tables are used to collect the data related with schedule based system and some are used for non schedule based transport system. The top layer expresses the existence of unique group data for each specific transport mode and they do not have any relation with other layers.

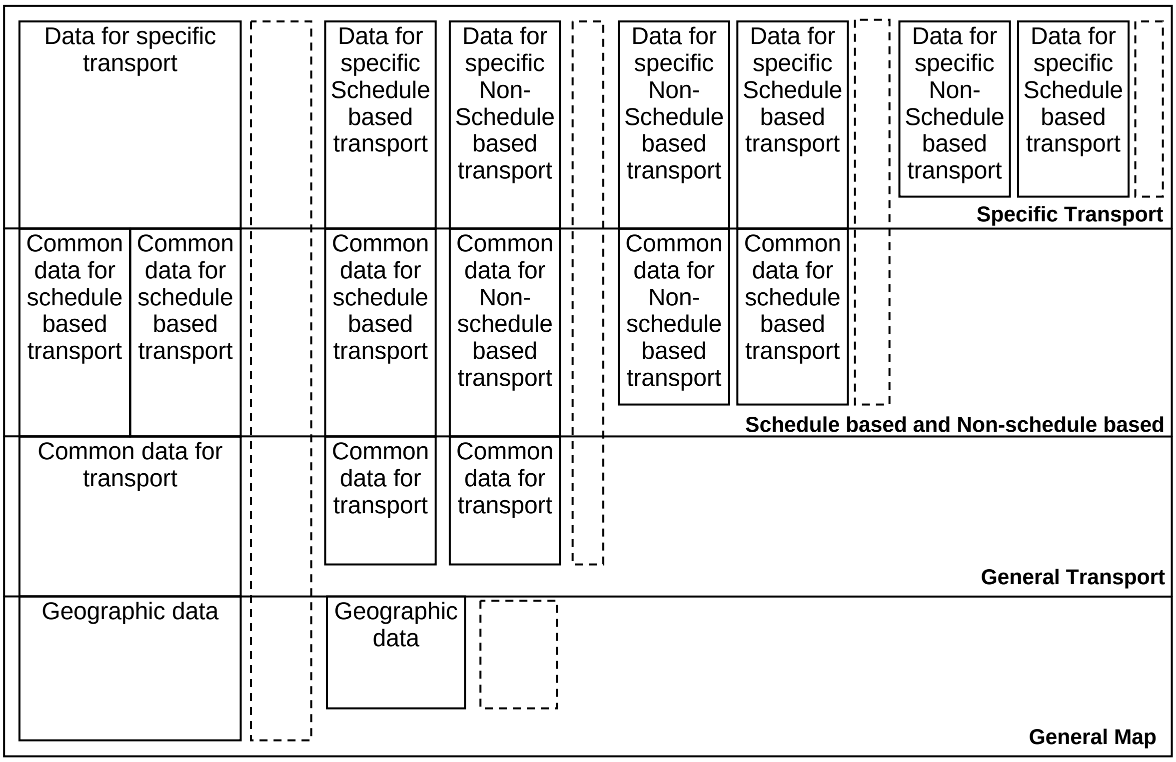


Figure 3: Physical structure of Four-layer database

## 3.5 Benefits of Layer database Model

The four-layer database model is able to reduce data redundancy because the common information for different types of transportation modes is collected in the lower layer and it ensures that there is a 'one-to-one' relationship between objects and the data collected for it (that is, more than one distinct record for each object is not recorded). For instance, roads are used by taxis, buses, private vehicles, motorcycles, etc and road data can be organized in a table and the detailed information for specific organizations can be classified by the attributes in each layer.

We now propose the data structure for the lower three-layers and we will use the railway transport data structure as an example of a specific transport mode data structure. In reality, there are various types of transport modes in our society and developers can develop for other specific transportation modes as necessary based on the four-layer database model. Therefore, layer structure is able to be extended for a specific transport system/mode and it can facilitate the development of transportation data management system.

In addition, the layer structure can assist in reducing program redundancy by sharing the same or similar programs and software components. For example, although data itself might be different, there are similar functions with relation to time scheduling for different types of schedule based transportation modes and they can be developed as general components and the special features for specific schedule based transport modes can be developed as program. Therefore, the general component for scheduling can be used for any kinds of schedule based transport mode.

Moreover, the layer database approach can reduce operations (e.g., developing programs, updating database).

The most important contribution from the four-layer database model is that it can support the reorganization of disparate transport organizations and, therefore, this is the goal of future integrated transportation system.

### 3.6 Data structure of Four-Layer database Model

In conceptual modelling for the four-layer database model, there are four relationship diagrams for the lower three layers. The top layer is for a specific transportation system/mode database and therefore, there may be many models in that layer. Therefore, in this paper, we will present model for the GMD, GTD, SBTD and NSBTD. The sample specific transport mode is railway transport and we will show how to implement the railway data structure based on the lower layer of four-layer database model in the remainder of this paper.

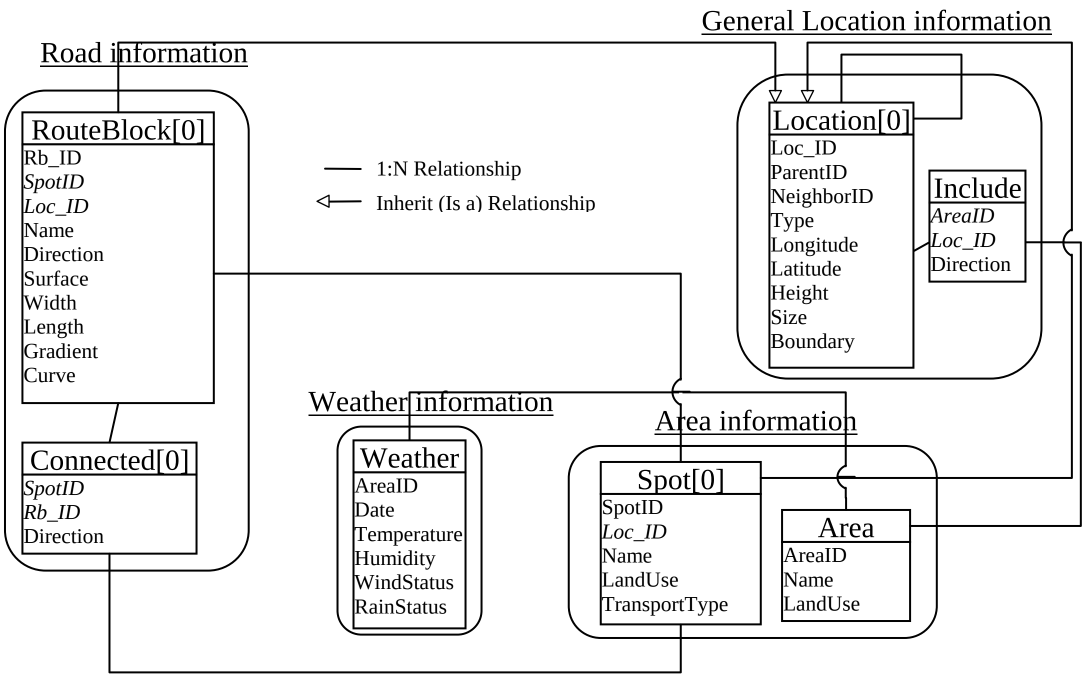


Figure 4: General Map database

Figure 4 shows a class diagram for the General Map Database. We divide the database into four groups of information.

- **General Location Information** includes two tables as follows; *Location:* generalizes the data 'spot' and 'route block' in order to simplify the existence of transport places and routes in large areas, *Include:* is an association between the 'area' and 'location' entities is 'include' because small locations are included in a large area. This relationship table is intended to record the associated information of large areas and small locations.
- **Road information** stores any kind of transport route that is used by vehicles. This group contains the routeBlock- and Connected-table. These tables are intended to record data for roads, rail lines, sea-lanes, air routes, etc.
- **Area Information** includes two tables as follows; *Area:* stores data about 'administrative regions', natural locations such as the 'sea' and 'mountains', and 'city', *Spot:* stores information about any kind of place which can be used to assist transport related activities, the stop or start of vehicles for the purposes of safety or change of course, allowing passengers to board or alight or load/unload cargo on freight vehicles and keep the vehicles for the purposes of maintenance, parking, etc. Some examples to be recorded in this table are hospital, road intersection, rail point, railway station, vehicle workshop, etc.
- **Weather Information** provides historical and forecasting weather data.

This data structure provides the way to share GIS data physically among organizations.
The second layer is General Transportation System. Figure 5 is the design of data structure. The General Transportation Database includes seven information groups as follows;

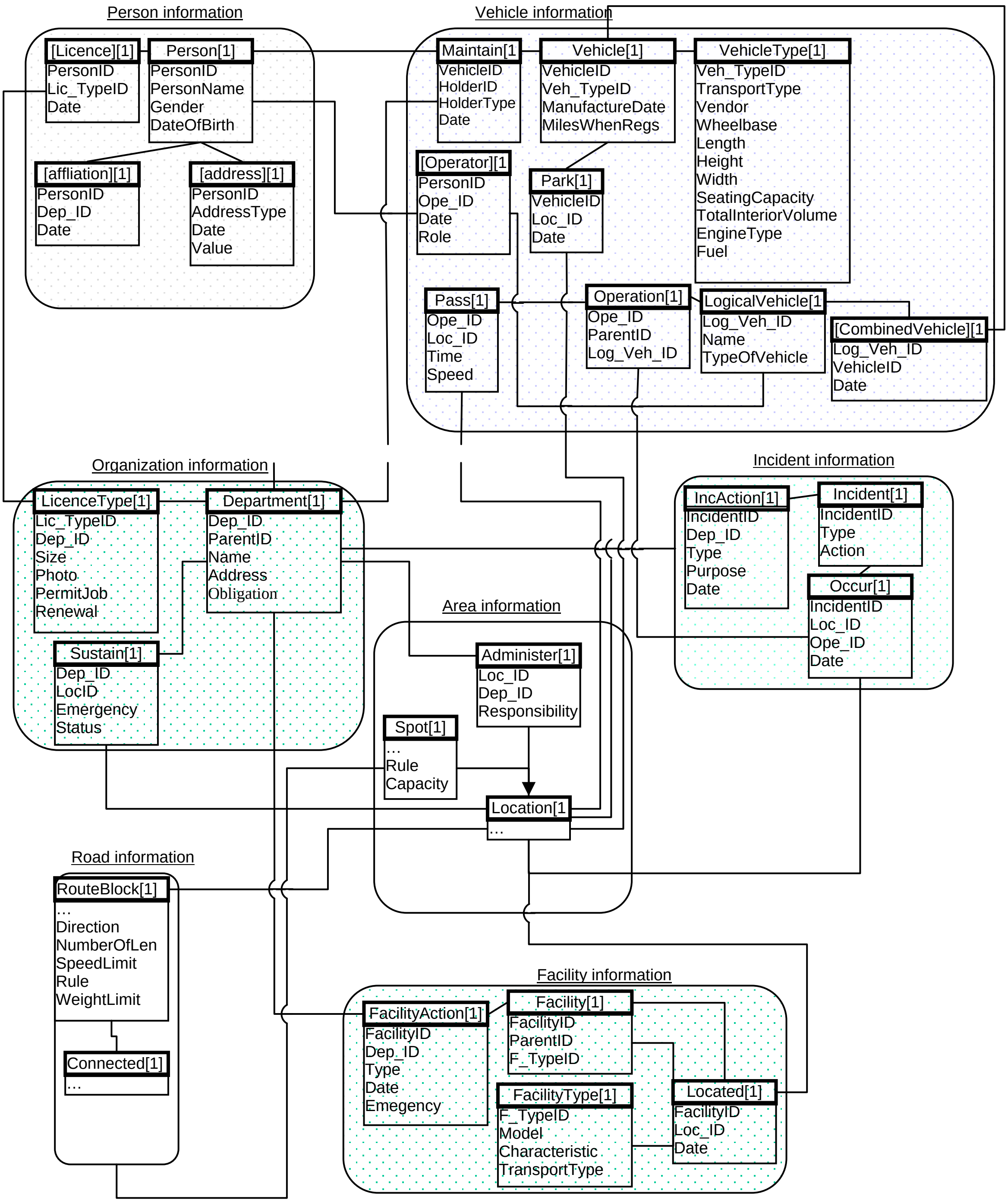


Figure 5: General Transport System

- **Road Information** and **Area Information** are inherited from General Map Database. *RouteBlock*[1] table is inherited from *RouteBlock*[0] of the General Map Database. The symbol "…" implies inheritance attributes. The remaining attributes are additional information that should be managed in the current database layer. *Connected*[1] table is inherited from Connected[0] of the General Map Database. Attributes of the table contains only a symbol "…", meaning there are no addition attributes in current database layer. Connected – Transport places, such as intersections, bus stops, are connected with route. This relationship exists between the 'place' and 'route block' entities. *Administer* **-** The administration on the specific location is done by the relevant organization or bureau. According to the above reasons, there is a relationship between 'administer' and 'department' and 'location' entities.

- **Person information** includes four tables as follows; *Person:* stores the biographical data of a person, such as their name, and birthday, *Affiliation:* stores employment information e.g., company name, date of employment, *Licence:* stores license information to identify their occupation, *Address:* records the residence information of a transport related person.
- **Vehicle Information** manages information about vehicles that can be used to transport people or freight. Examples include automobiles, aircraft, locomotives, passenger coach, and ships. This group contains nine tables as following; *VehicleType:* is assigned to store similar types of vehicles for different transportation modes e.g., registration number, colour, size, manufacturer, model, *LogicalVehicle:* stores data about logical existence of trips for vehicles for any kind of transportation mode, e.g., taxi, train, road train, *Operation:* manages various types of vehicle operations such as bus operations, train operations, airplane operations, etc., in the transportation network, *Operator:* stores information relating to a person who operates a vehicle and plays an important role for safety, efficiency, etc, *Maintain:* exists among the 'person', 'department' and 'vehicle' entities in GTD data structure because individual person might perform the maintenance of particular vehicles or within organizations in different types of transportation system, *CombinedVehicle:* associates between 'vehicle' and 'logical vehicle' entities and stores information about transport trips (e.g., rail cars are used for train), *Pass*: is relationship between the 'operation' and 'location' table, *Park:* stores parking information.
- **Organization Information** includes three tables as following; *Department*: represents any kind of organization, bureau, office, company, etc., that are related with the transportation system, *LicenseType:* is a term referring to any kind of authorization which are used to allow 'driver/operators' to operate a specific type of vehicle in the context of the transport mode for which the licence has been issued e.g., private vehicle license, rapid train driver license, and employee identification card, *Sustain:* is assigned between the 'department' and 'location' entities to sustain or maintain the transport places and routes in order to achieve the highest potential of efficiency and effectiveness.
- **Facility Information** includes four tables as follows; *Facility:* stores data about any type of transportation system that uses devices or materials for the purposes of safety, efficiency, reliability, etc, *FacilityType:* stores the information of same type of facility, *FacilityAction:* is assigned between the 'facility' and 'department' entities and maintains information of individual facility which will perform or was done by department, because the responsibility of management of facility is related with transport organization, *Located:* records the location of individual facility.
- **Incident information** includes three tables as follows; *Incident:* is a general term for the unexpected events which might have occurred in transportation system e.g., natural disasters, accidents, *Occur*: is assigned among 'operation', 'location' and 'incident' to record information relating to unexpected events which impact a location and vehicle operation, *IncAction:* stores information about how to recover from unexpected events by the relevant department in order to get the location back to its normal condition e.g., historical, current information and future responsibility of recovering incident.

Schedule based and Non-Schedule based Transportation System Database is the next layer of General Transportation System Database. The design of data structure of the two systems is shown in figure 6 and 7. In this case, the data structure is shared between organizations. The data themselves are different e.g., data for a Bus control system, or data for a train control system. Each organization can develop their transaction programs. The inherited tables are implied with symbol "[2]" and "[2*]". Beside these tables, we propose three new groups as follows;

- **Scheduling Information** manages information about the schedule of a vehicle. There are five tables in the followings; *TimeSchedule:* applies to any mode that uses a fixed 'schedule' of arrival/departure from fixed (and generally linearly related) geographical locations forming a 'route', *RouteSchedule*: is a term referring to the possibility of route settings for schedule based transport operations; *TicketType*: manage financial resources, the revenue information associated with passenger or cargo tickets, *Provide*: is the association between 'logical vehicle' and 'ticket type' table in SBTD data structure, and records the number of tickets that are available in a particular schedule based trip, *Comprise:* exists between the 'route schedule' and 'location' entities which are assigned the route schedule.

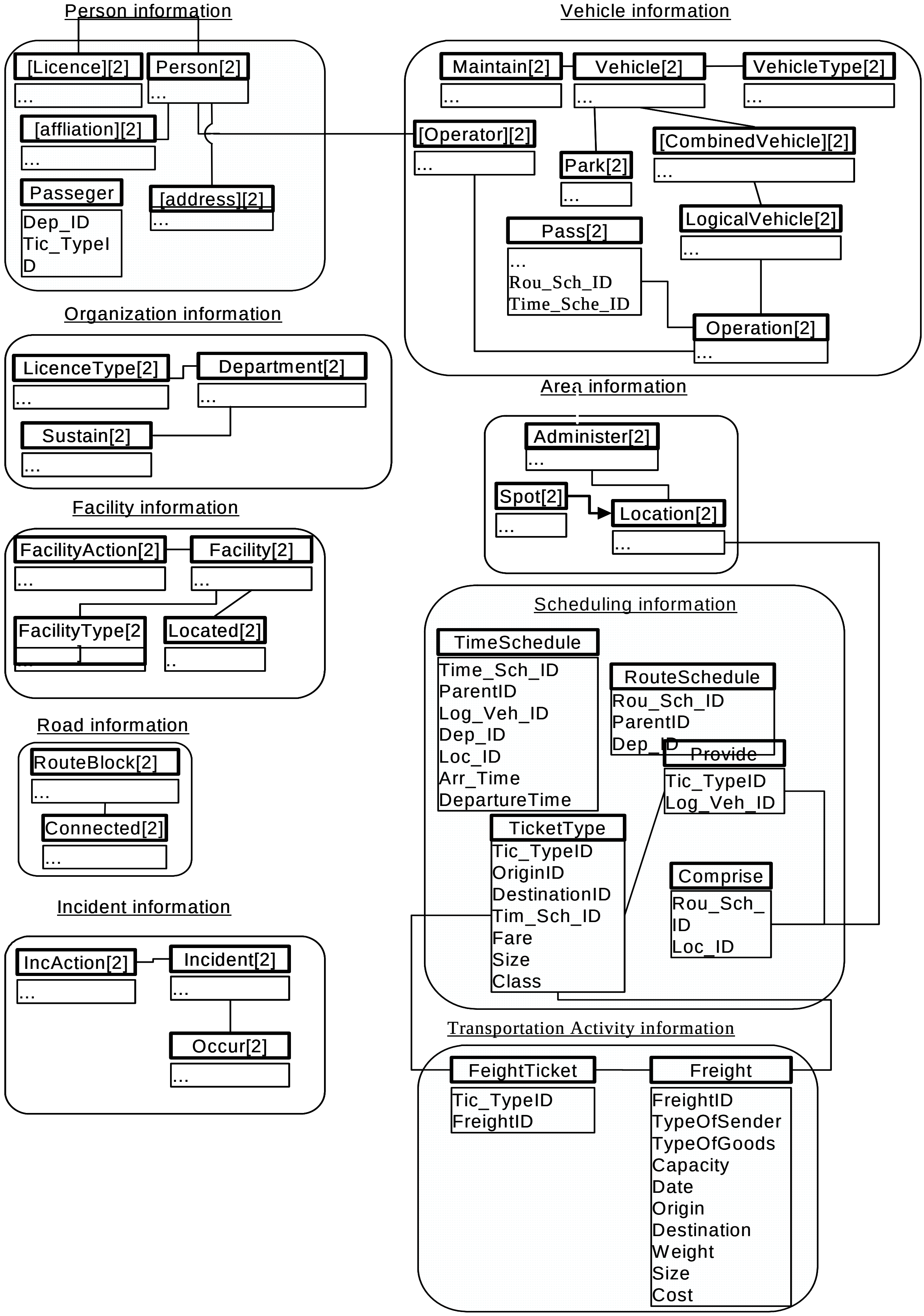


Figure 6: Schedule base Transportation System Database

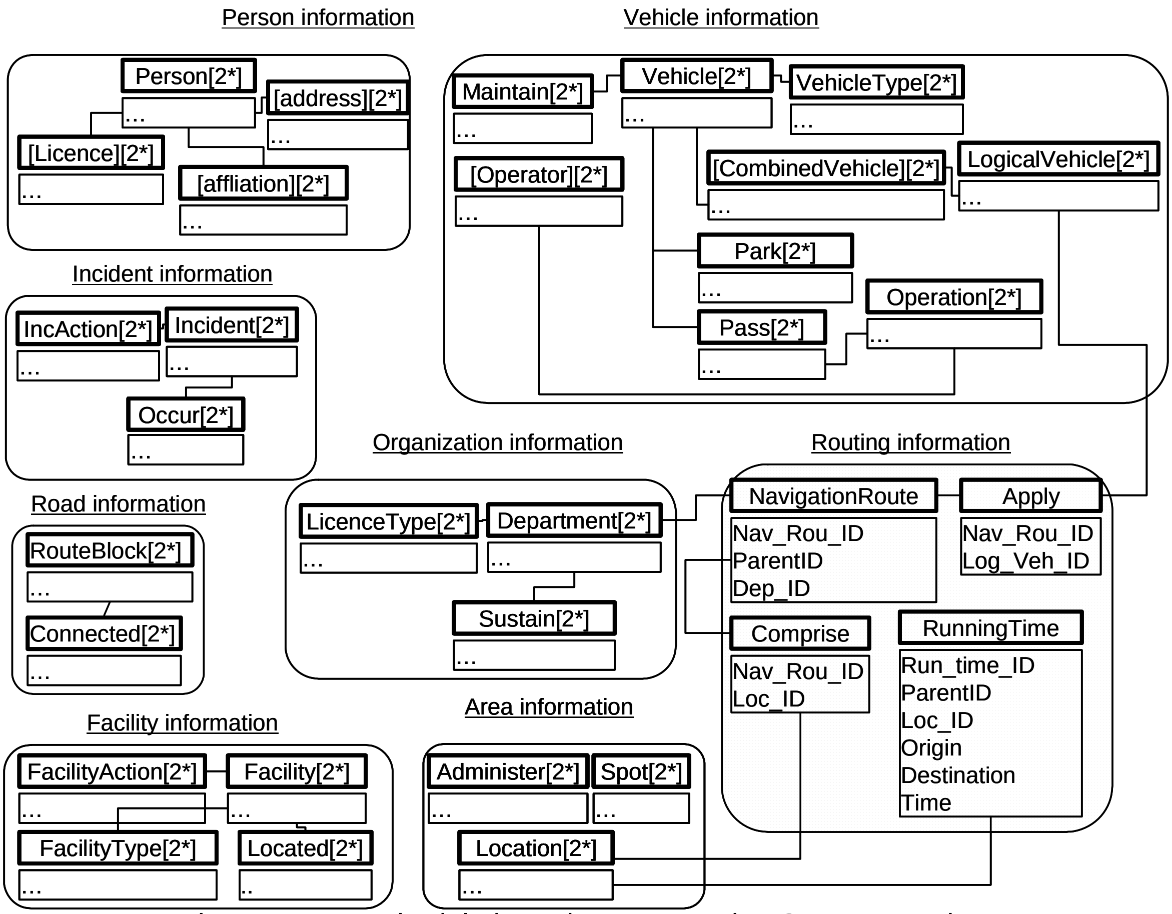

Figure 7: Non-schedule based Transportation System Database

- **Routing Information** manages information about navigation routes for vehicles. There are basically three tables as follows; *RunningTime:* supports the driving time or running time of the specific route for non-schedule based transportation modes, *NavigateRoute:* originates from the secondary middle layer of NSBTD data structure to recommend the most suitable route for non-schedule based operations e.g., shortest distance route, shortest time route, *Apply:* is assigned between the 'logical vehicle' and 'navigate route' entities of NSBTD data structure, and analyses some activities, such as driver behaviour, performance of control, etc.
- ***Passenger*** table is provided in Person Information group in order to record future plans, current conditions and historical sale of tickets based on the season.
- **Transportation Activity Information** stores data about freight. There are two tables in this information group. The first one is *Freight,* which records the associated information between the 'ticket type' and 'department' entities, a 'freight' relationship is assigned in SBTD data structure. Relevant department must sell the freight ticket for customers and this table is used to record the future plan, current condition and history of sold tickets based on the season. The second one is *FreightTicket*, which is a table which has a many-to-many relationship between the TicketType and Freight tables, which implies the (there are) different tickets for different types of freight transport.

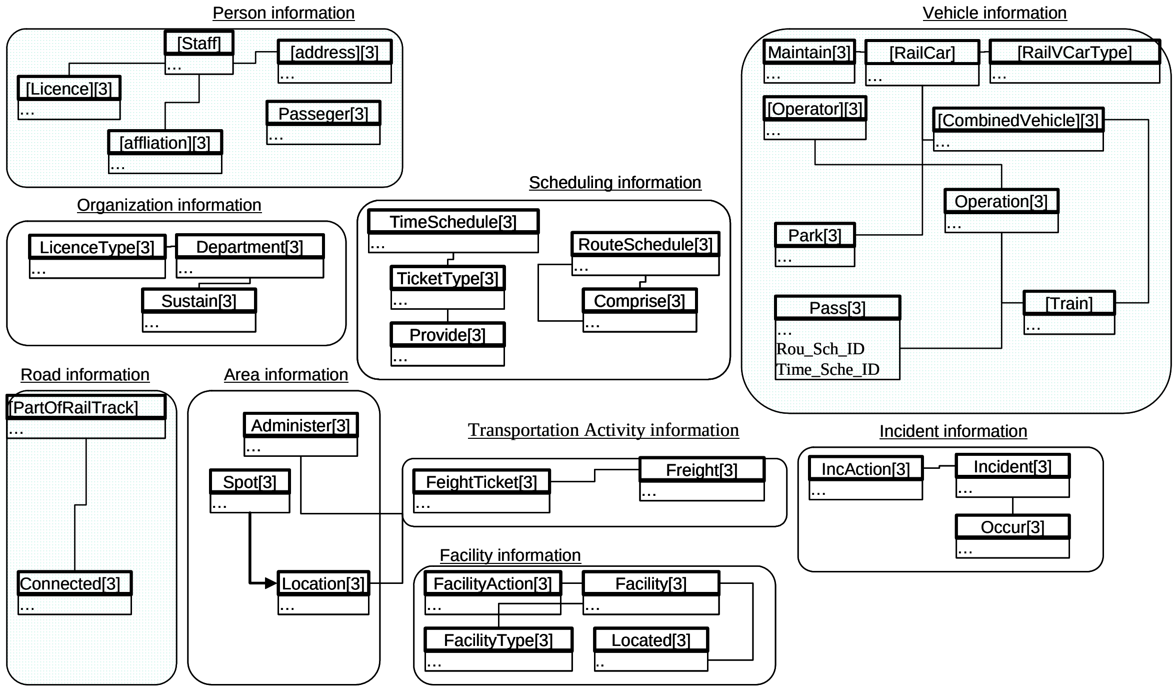


Figure 8: Railway Transportation System Database

Figure 8 is Railway Transportation System Database as an implementation of a specific transportation system. Beside the tables (with symbol “[3]”) inherited from Schedule Based Transportation database, there are four tables used for railway transport as follows; *RailCar*: stores data for any kind of railway vehicle and rolling stock which exists in rail transport, *RailCarType:* is a term for a type of rail car which is classified by the brand and model of rail car and is able to reduce the data redundancy in the rail car table because many of the same types of rail car might be used by rail transport if we record in the rail car table, and then there may be repeated information recorded, *Train:* is a combination of rail car and on the other hand train and is an expression of trips which are organized by a railway organization e.g., regular train operations and the train identification number, *Staff:* manages the human resources of rail transport including detailed profile of employees who are related with rail transport, *PartOfRailTrack:* represents for illustrating the detailed structure of rail track.

## 4 Conclusion

For integration of different types of transportation systems/modes, this paper proposed an architectural and physical design of the four-layer database model that consists of a general map layer, a general transportation layer, a schedule and a non-schedule based layer and a specific transportation layer from the top.

This design enables organizations to share GIS data in the IntegTS context and to develop software packages for transportation control.

The shared data and software packages may help organizations to construct their transportation information system as a part of the Integrated Transportation System.

## References

[1] N. Vogiatzis, H. Ikeda, J. Woolley, Y. He (2003), "Integrated Multi-nodal traffic Network systems", *Journal of the Eastern Asia Society for Transportation Studies*, Vol.5, October, pp. 2092-2107.

[2] H. Ikeda, N. Vogiatzis, W. Wibisono, B. Mojarrabi, and J. Woolley (2004), " Three Layer Object Model for Integrated Transportation System", *Proceedings of the 1st International Workshop on Object Systems and Systems Architecture*, Victor Habor, Australia.

[3] Friedrice, M., Noekel, K. (2004), "Extending transportation planning Models: From Strategic modeling to operational transit planning", *Proceedings of the 9th international conference on computer-aided scheduling of public transport* (CASPT), San Diego, California.

[4] Schlenoff, C., Balakirsky, S., Barbera, A., Scrapper, C., Ajot , J., Hui, E., and Pardes, M. (2004), "The NIST Road Network Database", *National Institute of Standards and Technology.*

[5] Joseph M. Sussman (2005), "Perspectives on Intelligent Transportation Systems", *Springer Science + Business Media, Inc*, pp. 157-165.

[6] Vogiatzis, N (2007), "On Organic Transportation and the Next Generation Transport Management Systems", *PhD Thesis, Transport Systems Centre: University of South Australia (Taylor, MAP, Ikeda H)*

[7] Vogiatzis, N, Felhmann S, Kelly J, Mitchell J, Chaudry W, Shuttleworth S, and Malallah W (2006), "Nexus II/IIa: Traffic Control System Research System", *Software Suite, Transport Systems Centre: University of South Australia (Vogiatzis N: project manager)*