TECHNICAL REPORT

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Transport information and control systems — Reference model architecture(s) for the TICS sector —

Part 2: Core TICS reference architecture

Systèmes de commande et d'information des transports — Architecture(s) du modèle de référence du secteur TICS —

Partie 2: Architecture de référence du noyau des TICS

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

— type 3, when a technical committee has collected data of different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

Technical Reports are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Attention is drawn to the possibility that some of the elements of this part of ISO/TR 14813 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TR 14813-2, which is a Technical Report of type 2, was prepared by Technical Committee ISO/TC 204, *Transport information and control systems*.

This document is being issued in the Technical Report (type 2) series of publications (according to subclause G.3.2.2 of Part 1 of the ISO/IEC Directives, 1995) as a “prospective standard for provisional application” in the field of transport information and control systems because there is an urgent need for guidance on how standards in this field should be used to meet an identified need.

This document is not to be regarded as an “International Standard”. It is proposed for provisional application so that information and experience of its use in practice may be gathered. Comments on the content of this document should be sent to the ISO Central Secretariat.

A review of this Technical Report (type 2) will be carried out not later than three years after its publication with the options of: extension for another three years; conversion into an International Standard; or withdrawal.

ISO/TR 14813 consists of the following parts, under the general title *Transport information and control systems — Reference model architecture(s) for the TICS sector:*

— *Part 1: TICS fundamental services.* This document presents the definition of 32 TICS fundamental services that are the informational products or services or applications areas provided to a TICS user.

— *Part 2: Core TICS reference architecture.* This document describes an abstract object-oriented system architecture based on the TICS fundamental services.

— *Part 3: Example elaboration.* This document refines the core TICS reference architecture (part 2) with some emphasis on traffic management.

— *Part 4: Reference model tutorial.* This document describes the basic terms, graphical representations and modelling views exploited in the object-oriented definition of the architecture development of parts 2 and 3.

— *Part 5: Requirements for architecture description in TICS standards.* This document describes the terminology and form to be used when documenting or referencing aspects of architecture description in TICS standards.

— *Part 6: Data presentation in ASN.1.* This document establishes the use of ASN.1 as the normal syntax notation to be used in standards for the TICS sector and a common message form for such ASN.1 based data elements.

Annex A of this part of ISO/TR 14813 is for information only.

Introduction

TC204/WG1 is a working group whose prime objectives are to provide services to ISO TC204 and its working groups. A specific mission of WG1 is to:

“Provide ISO TC204, its working Groups, related bodies and those involved in the TICS sector, with a reference model of Conceptual Reference Architecture(s) that show the structure and inter-relationships of the sector ...”

It is expected that there may well be more than one single TICS Architecture approach to be considered and documented and that existing architecture approaches will have previously-produced documentation developed according to disparate standards and conventions.

It is also implicit in the work being undertaken by WG1, that working group members will require a clear, well-structured understanding of the work of the following participant groups:

- Other TC 204 Working Groups
- CEN TC 278 Working Groups
- Japanese initiatives
- European Road Transport and Traffic Telematics programs
- US Intelligent Transportation Systems program
- Australian initiatives
- Canadian Initiatives

Full documentation of all possible architectural approaches is obviously not feasible given the high level of resources required to carry this out. Indeed full documentation and description of all possible approaches is undesirable as an item for Standardisation.

A defined and consistent approach is however required to facilitate the specification of architecture requirements to enable a clear view to be developed and presented of the work of each participant group This document is one of a set of WG1 documents intended to respond to stated WG1 objectives regarding the production of a TICS Reference Architecture.

In order to document an architecture, graphical and textual components of a model are required. WG1 has adopted a methodology based on the Unified Modelling Language (UML) for documenting the TICS Reference Architecture. A tutorial on the UML is provided in Part 4. UML is a visual modelling language for building object-oriented and component-based systems. A commercially available Computer Aided Software Engineering (CASE) tool has been used by WG1 to document the Architecture. While the tool is a commercial product, UML is open and non-proprietary.

Transport information and control systems — Reference model architecture(s) for the TICS sector — Part 2: Core TICS reference architecture

1 Scope

The architecture of an information and control system merges hardware and software considerations into a coordinated and integrated system view. The system architecture is a high level abstraction, or model, of the system. A system architecture should embrace both today's applications and the applications that are expected in the future. Architecture begins with the definition of the conceptual services (e.g. Part 1 - TICS fundamental services). There are several identifiable stages of system architecture development:

— 1. Reference architecture

— 2. Logical architecture

— 3. Physical architecture

A reference architecture is the first of all architectures. It is a concise generic framework which guides the development of more concrete system architectures. It is large enough that distinct concepts are not merged out of necessity and small enough that it does not become unwieldy.

A most significant example of a reference architecture in information systems is the Reference Model of Open Systems Interconnection (often called the seven layer model) developed by ISO in the 1970's. This model has underpinned the development of all modern computer networks, allowing services such as global networking, of which the prime example is the Internet, to become a reality.

A reference architecture is generic and non-prescriptive and captures the concepts of the system. A logical architecture elaborates the conceptual behaviour, and in so doing it provides more detail about the modularity. A physical architecture is reached when the actual distribution of the system modules is defined, thus leading to important implications for communications.

There is no firm demarcation between a reference architecture and a logical architecture. Thus the essence of behaviour and modularity is present in a reference architecture. The TICS Reference Architecture developed by WG1 shows important inter-relationships that arise in the provision of the services of the sector. However the TICS Reference Architecture is more abstract than, for example, the logical architecture of the US National Architecture.

It is envisioned that the TICS Reference Architecture will be used by the TC204 Working Groups to develop their own logical and physical architectures in a cohesive manner.

Some TICS Fundamental Services are already well developed by the industry, while others are less mature. Therefore the TICS Reference Architecture does not have a uniform granularity across all services. This characteristic is a direct result of the fore mentioned requirement that architecture embrace the applications that are intended in the future. This suggests one of the ways in which the architecture will undergo change in the future.

Architectures may present only static characteristics or both static and dynamic characteristics. Dynamic characteristics may be seen as belonging solely to the design/implementation stages of system development. However by including dynamic characteristics at the reference architecture stage one gains important insights into the static architecture. Thus two orthogonal views of architecture are presented:

- 1. static relationship view (class diagram)
- 2. dynamic interactive view (sequence diagram)

This part of ISO/TR 14813 develops a core reference architecture. The static scope is determined by deriving the system boundary and the use cases from an analysis of the TICS fundamental services (part 1 of ISO/TR 14813).

The Core Reference Architecture is a reference for the development of national architectures.

Part 3 of ISO/TR14813 elaborates the core reference architecture by refinement of two orthogonal views. The elaboration calls upon domain expertise that would be provided by other TC204 Working Groups in the development of ISO standards or by national groups developing national architectures and standards.

The core reference architecture is described in clauses 5 to 8. Clause 5 introduces the architecture at a highly abstract level. Clause 6 defines all the actors. Clause 7 derives all the use case from the TICS fundamental services and develops eight use case diagrams. Clause 8 defines an abstract collection of classes and develops a set of sequence diagrams, one per use case diagram.

Readers should refer to Part 4 of ISO/TR 14813 (Tutorial) for an introduction to the modelling views used in this part and the methodology applied. The methodology is repeated in Annex A.

2 Normative references

The following normative documents contain provisions that, through reference in this text, constitute provisions of this part of ISO/TR 14813. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO/TR 14813 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO/TR 14813-1:1999, *Transport information and control systems – Reference model architecture(s) for the TICS sector – Part 1:TICS fundamental services.*

ISO/TR 14813-3:2000, *Transport information and control systems – Reference model architecture(s) for the TICS sector – Part 3: Example elaboration.*

ISO/TR 14813-4:2000, *Transport information and control systems – Reference model architecture(s) for the TICS sector – Part 4: Reference model tutorial.*

3 Terms and definitions

For the purposes of this part of ISO/TR 14813, the following semantic definitions apply.

3.1
The **Unified Modeling Language** (UML) is the industry-standard language for specifying, visualising, constructing, and documenting the artefacts of software systems. It simplifies the complex process of software design, making a “blueprint” for construction.[1]

3.2
A **use case** is a coherent unit of functionality provided by a system or class as manifested by sequences of messages exchanged among the system and one or more outside interactors (called actors) together with actions performed by the system.

[1] http://www.rational.com/uml/

3.3
An **actor** is a role of an object or objects outside of a system that interacts directly with it as part of a coherent work unit (a use case). An Actor element characterises the role played by an outside object; one physical object may play several roles and therefore be modelled by several actors.

3.4
Use case diagrams show elements from the use case model. The use case model represents functionality of a system or a class as manifested to external interactors with the system.

There are several standard relationships among use cases or between actors and use cases.

Communicates - The participation of an actor in a use case. This is the only relationship between actors and use cases.

Uses - A uses relationship from use case A to use case B indicates that an instance of the use case A will also include the behavior as specified by B.

To reinforce the externality of actors a system boundary separates the actor symbols from the use case symbols.

3.5
A **package** is a grouping of model elements. Packages themselves may be nested within other packages. A package may contain both subordinate packages and ordinary model elements. The entire system description can be thought of as a single high-level *system* package with everything else in it. All kinds of UML model elements and diagrams can be organised into packages.

Packages own model elements and model fragments and are the basis for configuration control. Each model element can be directly owned by a single package, so the package hierarchy is a strict tree.

Packages can reference other packages so the usage network is a graph. Relationships drawn between package symbols denote relationships between at least some of the elements in the packages. A dependency relationship implies one or more dependencies among the model elements, in which a change in the targeted element may require a change in the source element.

3.6
A **class** is the descriptor for a set of objects with similar structure, behavior, and relationships. UML provides notation for declaring classes and specifying their properties, as well as using classes in various ways. Classes are declared in class diagrams and used in most other diagrams. UML provides a graphical notation for declaring and using classes, as well as a textual notation for referencing classes within the descriptions of other model elements.

3.7
A **class diagram** is a graph of Classifier elements connected by their various static relationships. (Note that a ‘’class’’ diagram may also contain interfaces, packages, relationships, and even instances, such as objects and links. Perhaps a better name would be ‘’static structural diagram’’ but ‘’class diagram’’ is shorter and well established.)

3.8
An **object** represents a particular instance of a class. It has identity and attribute values. The same notation also represents a role within a collaboration because roles have instance-like characteristics.

3.9
An **operation** is a service that an instance of the class may be requested to perform. It has a name and a list of arguments.

3.10
A binary **association** is an association among exactly two classes (including the possibility of a reflexive association from a class to itself).

3.11
Generalization is the taxonomic relationship between a more general element and a more specific element that is fully consistent with the first element and that adds additional information. It is used for classes, packages, use cases, and other elements.

3.12
A **sequence diagram** represents an **Interaction**, which is a set of messages exchanged among objects within a collaboration to effect a desired operation or result. A sequence diagram shows an interaction arranged in time sequence. In particular, it shows the objects participating in the interaction by their ''lifelines'' and the messages that they exchange arranged in time sequence. It does not show the associations among the objects.

In addition to the UML definitions cited above, the methodology described in Part 4 and Annex A uses some additional semantics.

3.13
The **system boundary** depicted in a sequence diagram maps to the same entity in a use case diagram. Thus any interaction emanating or terminating in the system boundary involves an actor.

In the methodology classes are invented for one of three purposes: information, control and interface.

An information class defines objects, which will store data relevant to the operation of the system and the actors and maintain that data with database like services.

A control class defines objects whose primary purpose is to implement the functions of the system.

An interface class defines objects that perform the data presentation and application interfaces for the actors.

3.14
The **architecture boundary** divides the interface classes from those classes, which form the actual architecture, namely the control classes and the information classes.

In the sequence diagrams developed in later clauses there is often an implicit interaction across the system boundary involving an actor. This may be implied whenever a message is initiated or terminated at an interface class.

4 Symbols and abbreviated terms

4.1 Use Case diagram

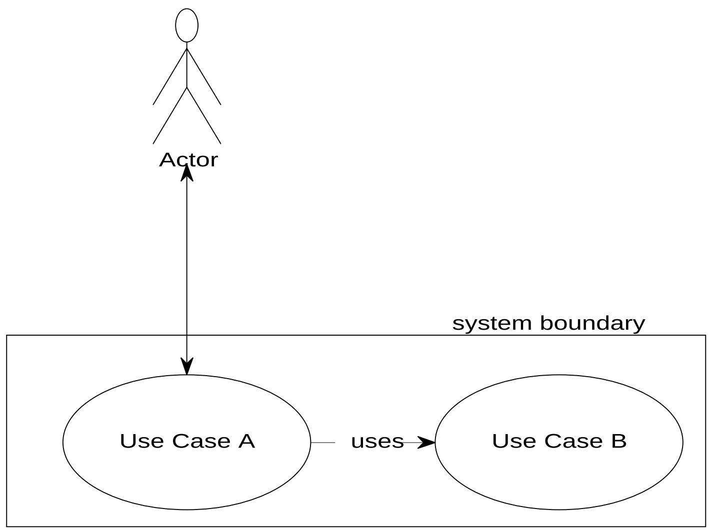

Figure 1 — Use Case diagram

4.2 Package Diagram

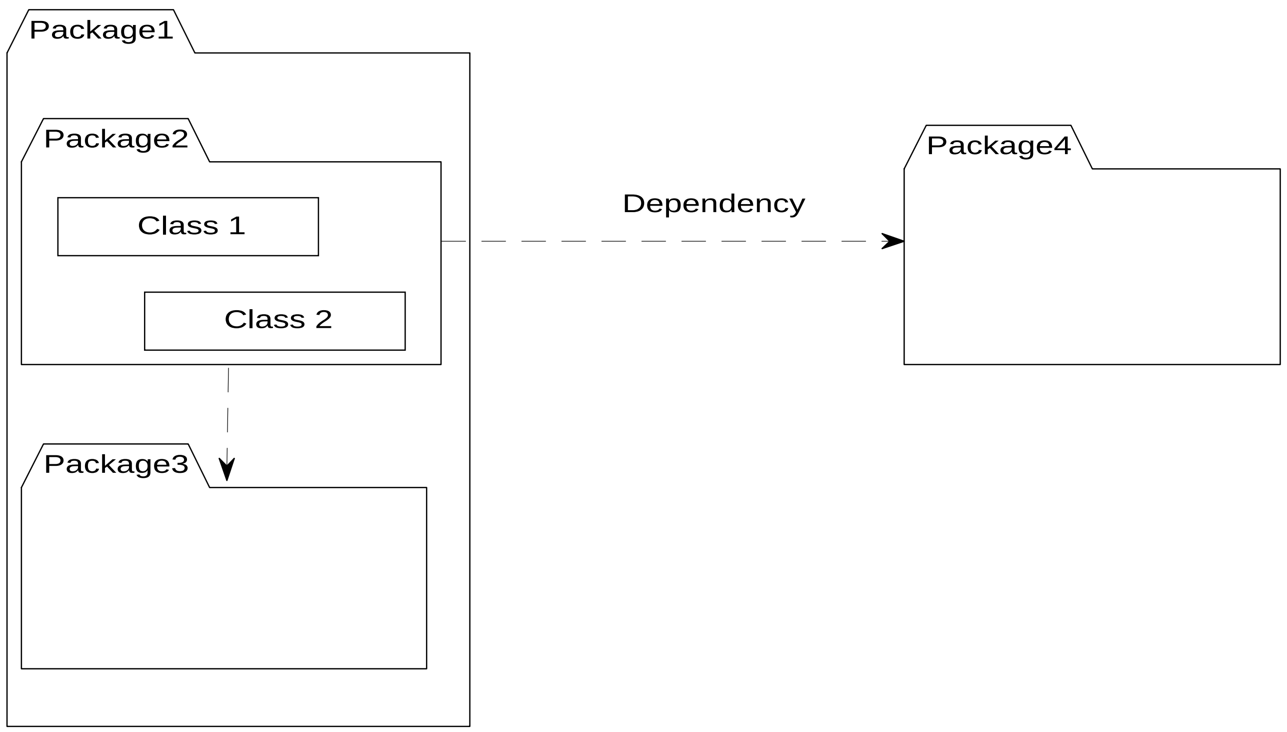

Figure 2 — Package Diagram

4.3 Class diagram

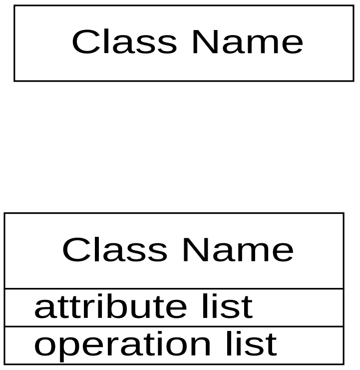

Figure 3 — Class diagram

4.4 Association Diagram

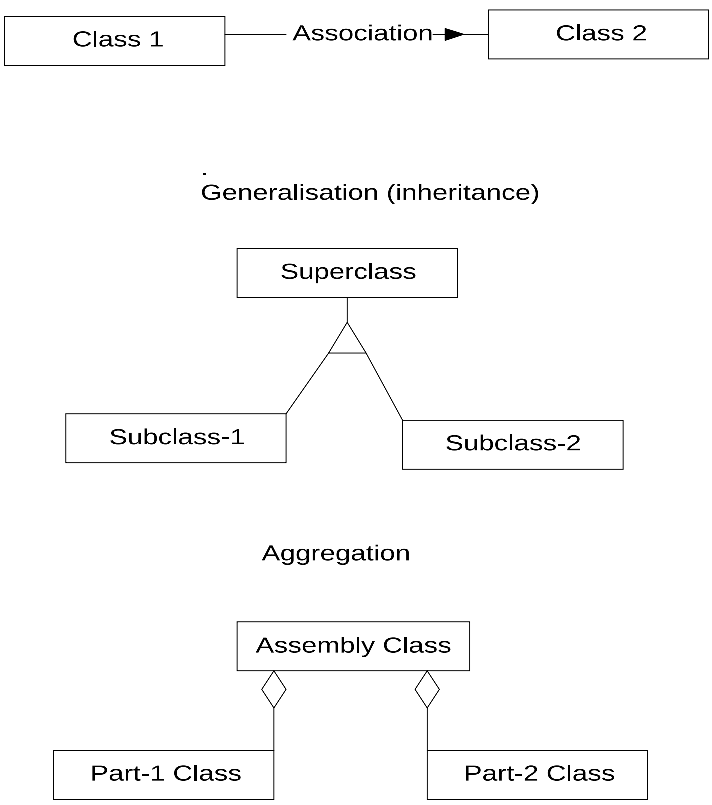

Figure 4 — Association diagram

4.5 Sequence (Interaction) Diagram

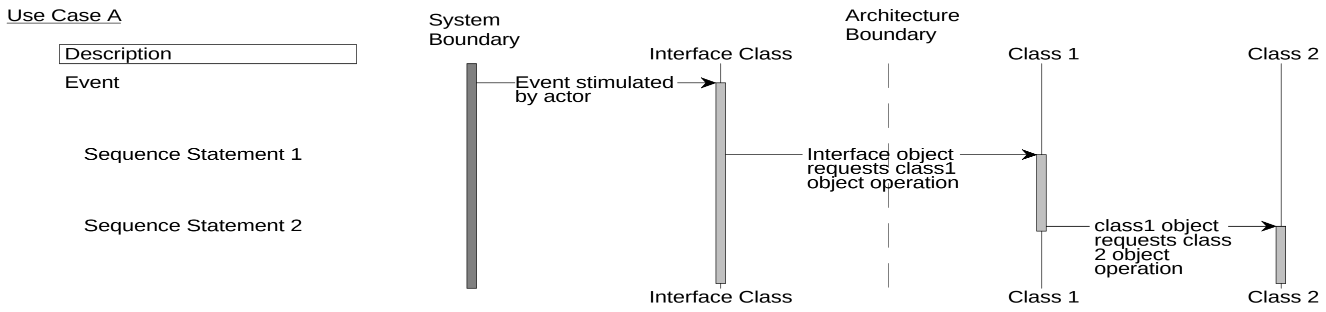

Figure 5 — Sequence (Interaction) diagram

5 Overview of the Core TICS Reference Architecture

The purpose of this clause is to define a concise overview of the TICS Reference Architecture expressed in one use case diagram and one package diagram[2]. These diagrams are top-level diagrams, that is, they are a global model of TICS expressed in the two UML views. They can be considered as abstract[3] aggregations having the coarsest granularity.

In the following clauses a Core TICS Reference Architecture is developed using more views and several diagram types. This clause is a starting point and concisely defines the scope of the architecture in diagram form with accompanying descriptions. Once the later clauses have been developed the model views in this clause could be considered to be a separate high level description of the architecture.

The use case diagram and the package diagram form complementary views of the abstract reference architecture. The use case is primarily a requirements specification with a precise identification of the boundary separating the external systems and users from the TICS system. The package diagram defines the conceptual modules. Together these two models provide a basis on which to build the more concrete elements of the architecture that will deliver the services specified.

The development begins by citing the TICS fundamental services from ISO/TR 14813 Part 1 in Table 1.

5.1 Generalised Use Cases in the Core TICS Reference Architecture

This clause defines the TICS Reference Architecture by a set of top level or aggregate use cases. These are depicted in the use case diagram of Figure 6 in association with actors of an equivalent level. The use cases have been defined in one to one correspondence with the Service Categories specified in the first column of Table 1.

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[2] Note: The development of the reference architecture in this and subsequent clauses involves a significant naming exercise. The names have been chosen with due regard for their use in existing technology. However, alternative names may arise in different contexts.

[3] See ISO/TR 14813 Part 4 for definition and discussion of abstraction.

Table 1 — Service Grouping

Service Category	Service Number	Service Name
Traveller Information	1	Pre-trip Information
	2	On-trip Driver Information
	3	On-trip Public Transport Information
	4	Personal Information Services
	5	Route Guidance and Navigation
Traffic Management	6	Transportation Planning Support
	7	Traffic Control
	8	Incident Management
	9	Demand Management
	10	Policing/Enforcing Traffic Regulations
	11	Infrastructure Maintenance Management
Vehicle	12	Vision Enhancement
	13	Automated Vehicle Operation
	14	Longitudinal Collision Avoidance
	15	Lateral Collision Avoidance
	16	Safety Readiness
	17	Pre-crash Restraint Deployment
Commercial Vehicle	18	Commercial Vehicle Pre-clearance
	19	Commercial Vehicle Administrative Processes
	20	Automated Roadside Safety Inspection
	21	Commercial Vehicle On-board Safety Monitoring
	22	Commercial Vehicle Fleet Management
Public Transport	23	Public Transport Management
	24	Demand Responsive Transport Management
	25	Shared Transport Management
Emergency	26	Emergency Notification and Personal Security
	27	Emergency Vehicle Management
	28	Hazardous Materials and Incident Notification
Electronic Payment	29	Electronic Financial Transactions
Safety	30	Public Travel Security
	31	Safety Enhancement for Vulnerable Road Users
	32	Intelligent Junctions and Links

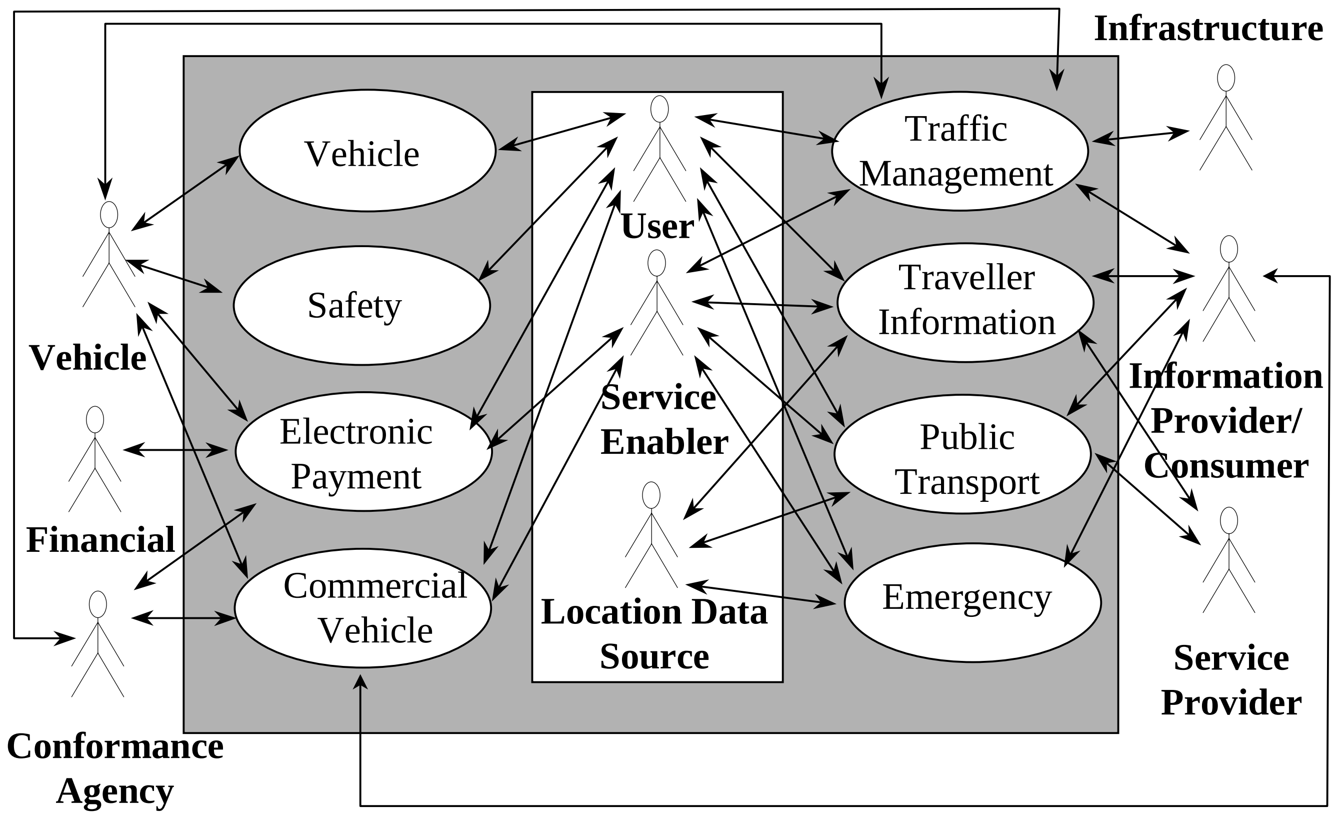

Figure 6 — Core TICS Reference Architecture Top Level Use Case Diagram. A set of generalised use case and actors that define the scope of the core TICS reference architecture

Traveller Information
The transaction sequences of this use case cover journey planning and confirmation, route guidance and yellow pages information and services.

Traffic Management
The transaction sequences of this use case cover the range of traffic control and management operations supported by TICS.

Vehicle
The transaction sequences of this use case cover all automated vehicle operation both in-vehicle and automated highway.

Commercial Vehicle
The transaction sequences of this use case cover commercial vehicle and goods transportation activities which involve global information stored and accessed by TICS.

Public Transport
The transaction sequences of this use case cover the scheduling, dispatching, operation and booking of public transport services.

Emergency
The transaction sequences of this use case cover emergency operations stemming from roadway incidents or security violations.

Electronic Payment
The transaction sequences of this use case cover fee collection systems concerning vehicle related transport services such as toll, parking and route guidance as well as fare collection and advanced payments for a wide range of services.

Safety
The transaction sequences of this use case cover automated safety services.

5.2 Generalised Actors in the Core TICS Reference Architecture

This clause identifies the set of actors that interact with TICS as shown in Figure 6. By defining these actors further illumination of the transaction sequences involved in the use case of 5.1 may be developed.

Conformance Agency
This actor represents the external entity types which receive reports of violations detected by various TICS facilities, e.g. traffic infringements, individual vehicle emissions, toll violations, commercial vehicle driver violations, etc. This actor also provides and monitors information about all drivers, vehicles, commercial vehicle credentials and taxes.

Financial
This actor represents the agent types that provide payment means to the User, collect payments, and process aggregated transactions so that the Transport and Service Providers receive payment from the issuers of credit.

Information Provider/Consumer
This actor represents those classes which perform unilateral roles with respect to TICS in that for each role they are either a provider of information or a consumer of information.

Infrastructure

This actor represents the systems which provide complementary services to the road based Transport System. There is a mutual exchange of information with TICS so that both systems may perform their services.

Location Data Source
This actor represents any external entity which provides accurate position information.

Service Enabler
This actor represents a diverse set of operators and systems which perform privileged interactions with the TICS system, thereby contributing to the operation of the Transport System.

Service Provider
This actor represents the providers of external services mediated by the TICS system.

User
This actor represents all the human roles which obtain end user service from the Transport System.

Vehicle
This actor represents the classes of vehicle that contain components of the TICS system or which are recognised in some way by the TICS system.

5.3 Generalised Packages of the Core TICS Reference Architecture

In Figure 7 the Core TICS Reference Architecture *system* package is presented. It is composed of a number of conceptual *subsystem* packages. Only one level of a package hierarchy is shown at this stage. There are no dependency relationships shown because at this level there is likely to be mutual dependencies between almost every pair of packages. The major interactions are described below.

Roadway
This package controls the operation of the roadway network, thus covering almost all the use case transactions in Traffic Management. It interacts with all the other packages as described below.

Transport
This package plans and controls the movement of goods and people on the roadway network. It interacts with the Roadway package for the interchange of information about the status of the roadway network and the intentions in planned journeys. It interacts with the other packages as described below.

Vehicles
This package manages the automated aspects of vehicle operation. It interacts with the Roadway package for safety and resource management functions. It interacts with the other packages as described below.

Events
This package controls all events including roadway incidents, roadway emergencies and other emergencies. It interacts with the Roadway package in relation to roadway events. It interacts with the Transport package in relation to roadway events that affect transport planning, and the Vehicles package in relation to emergencies.

Payment
This package controls the payment for all services including automated payment for use of resources by vehicles. It interacts with the Roadway package in relation to resource charging, and Transport package in relation to journey payments.

Roadside Peripherals
This package provides all interfaces with traffic and the environment.

Operating Interfaces
This package provides interfaces with a range of actors, both human operators and systems.

Travel Terminals
This package provides interfaces with all sub types of user actor.

Vehicles Interfaces
This package provides interfaces on board the vehicle, both interactive and sensing.

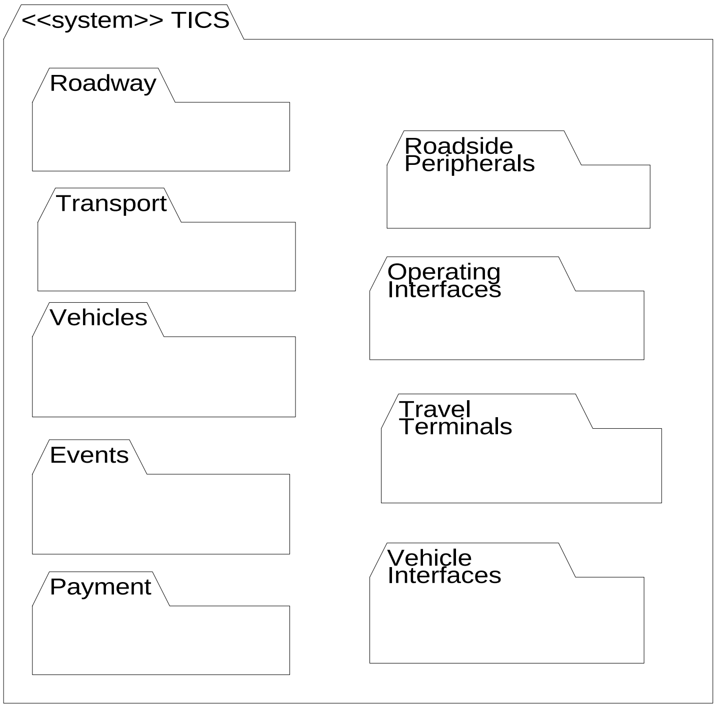

Figure 7 — Core TICS Reference Architecture Top Level Packages The diagram defines the conceptual packages which comprise the TICS system package

6 Actors associated with the Core TICS Reference Architecture

An actor is a class external to the system. The relevant actors are those whose objects interact with TICS. Thus an actor may be a role performed by a human or it may be a type of system[4].

Some obvious candidates were excluded as actors because they were passive with respect to TICS. For example environment is not an actor even though input is received about the environment. This input is developed by interface classes of TICS which are physically connected to hardware sensors. Similarly traffic is not an actor.

The actor classes associated with TICS are defined in this clause. These actors are presented as hierarchies based on root classes defined in Figure 6. The names of these actors have been selected with due consideration of existing terminology.

As shown in Figure 6, the *User* actor and the *Service Enabler* actor have many interactions with the use cases. Thus these base classes could be expected to have the larger actor hierarchies.

6.1 User

This actor represents all the human roles which obtain end user service from the Transport System. Actors identified with these roles are shown hierarchically in Figure 8.

[4] Although an actor is not necessarily a human it is always represented by a 'stick figure' in the use case diagrams, and labelled with its class name.

6.1.1 Traveller

This actor represents any individual (human) who uses transportation services. At the time that data is passed to or from the actor the individual may be an intending driver, pedestrian, passenger or any of the sub-classes. The data provided can be for pre-journey planning or multi-modal personal guidance, including assistance in an emergency. Subsequent to receipt of pre-journey information, a Traveller may become a vehicle driver, a passenger, or a pedestrian.

6.1.2 Forwarder

This actor is the party arranging the carriage of goods including connected services and/or associated formalities on behalf of a consignor or consignee.

6.1.3 Consignor/Consignee

This actor represents both an individual or an organisation that prepares a bill of lading by which a carrier is directed to transport goods from one location to another (consignor or shipper) and the party by whom the goods, cargo or containers are to be received and accepted (consignee).

6.1.4 Pedestrian

This actor is a specialised Traveller who is not using any type of vehicle (including bicycles) as a form of transport. Pedestrians may comprise those on foot and those in wheelchairs. They provide input (e.g. a request for right of way at an intersection) and receive safety warnings.

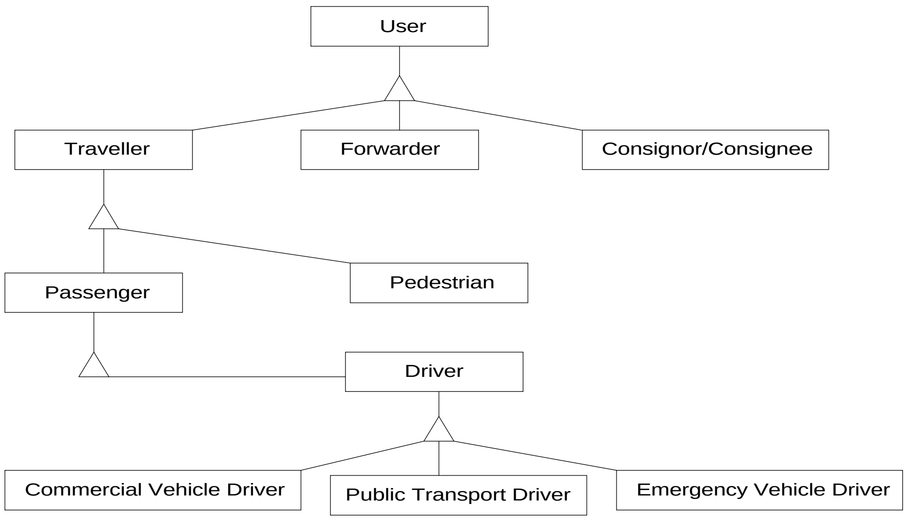

Figure 8 — The hierarchy of actors of type User

6.1.5 Passenger

This actor represents an individual or group on board a vehicle. They can derive numerous traveller services.

6.1.6 Driver

This actor represents the human entity that operates a licensed vehicle or cycle on the roadway. Included are cyclists, motor cyclists, operators of private, public transport, and commercial, and emergency vehicles where the transaction is not particular to the type of vehicle. Thus this actor originates driver requests and receives driver information that reflects the interactions which might be useful to all drivers, regardless of vehicle classification. The Driver actor is the operator of the basic Vehicle actor. Information and interactions which are unique to drivers of a specific vehicle type (e.g., fleet interactions with public transport, commercial, or emergency vehicle drivers) are covered by special actors.

6.1.7 Emergency Vehicle Driver

This actor represents the Driver that operates an ambulance, fire, rescue or other emergency vehicle. This actor uses a special TICS vehicle interface.

6.1.8 Commercial Vehicle Driver

This actor represents the Driver that operates a commercial vehicle such as a freight vehicle. This actor uses a special TICS vehicle interface.

6.1.9 Public Transport Driver

This actor represents the Driver that operates a pubic transport vehicle. This actor uses a special TICS vehicle interface.

6.2 Service Enabler

This actor represents a diverse set of operators and systems which perform privileged interactions with the TICS system, thereby contributing to the operation of the Transport System. The actors generalised in the Service Enabler actor are shown in Figure 9.

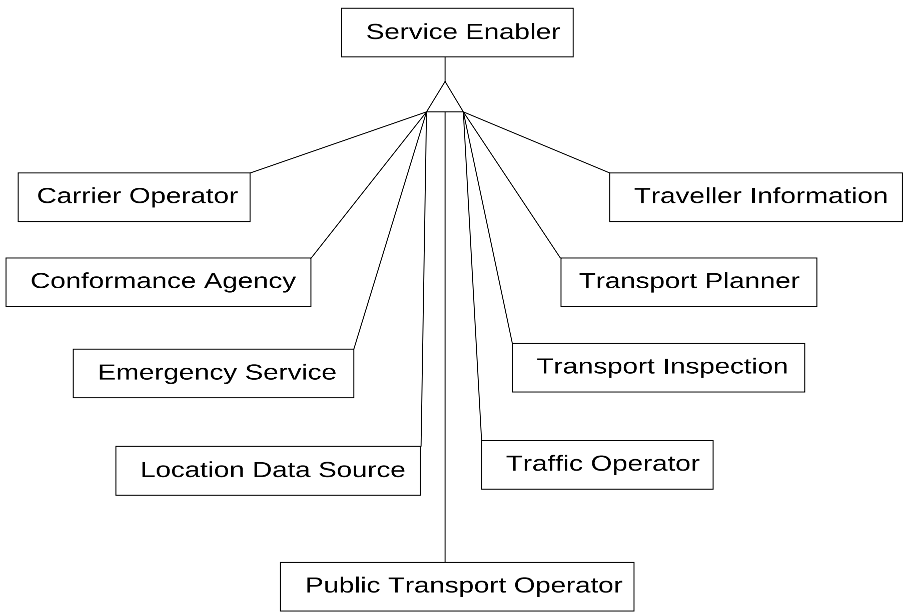

Figure 9 — The hierarchy of actors of type Service Enabler

6.2.1 Carrier Operator

This actor represents the human entities that are responsible for the dispatching and management of Commercial Vehicle fleets (e.g. traditional Fleet Managers). It may be many people in a large transport organisation but it can also be a single person (owner driver) in the case of single fleet vehicles. This actor provides instructions and co-ordination for Commercial Vehicles, including electronic clearance and tax filing, and receives the status of the Vehicles in the fleet that they manage. The actor is expected to interface with TICS on a regular basis to enhance productivity.

6.2.2 Conformance Agency

This actor represents the external entity types which receive reports of violations (e.g. traffic infringements, individual vehicle emissions, toll violations, commercial vehicle driver violations, etc.) detected by various TICS facilities. This actor also provides and monitors information about all drivers, vehicles, commercial vehicle credentials and taxes.

6.2.3 Emergency Service

This actor represents the human entity or system that monitors all TICS emergency requests (e.g. E911 in the US), and sets up pre-defined responses to be executed by an emergency management system. The actor may also override predefined responses where it is observed that they are not achieving the desired result. This actor includes dispatchers who manage an emergency fleet (police, fire, ambulance, hazardous materials, etc.) or higher order emergency managers who provide response coordination during emergencies.

6.2.4 Location Data Source

This actor represents an external entity that provides accurate position information. External systems which use GPS, terrestrial trilateration, or vehicle inputs are potential examples. This actor contains sensors such as radio-position receivers (e.g. GPS) and (or) dead reckoning sensors (e.g. odometer, differential odometer, magnetic compass, gyro, etc.). This implies that the functionality associated with developing an absolute position is outside the TICS system and will not be directly modelled by the logical or physical architecture representations of the system.

6.2.5 Public Transport Operator

This actor represents the human entities that are responsible for planning the operation of public transport fleets, including monitoring and controlling the public transport route schedules. This comprises planning routes and schedules for either daily use or for special occasions. This actor also represents the human entities that are responsible for all aspects of the public transport operation including planning and management. They actively monitor, control, and modify the public transport fleet routes and schedules on a day to day basis. The modifications will be to take account of abnormal situations such as vehicle breakdown, vehicle delay, etc. These personnel may also be responsible for demand responsive public transport operation.

6.2.6 Traffic Operator

This actor represents the human entity that directly interfaces with vehicle traffic operations. It also includes those personnel who schedule road maintenance and construction and cooperate to ensure that impacts on traffic flow are best managed. These personnel interact with traffic control systems, traffic surveillance systems, incident management systems, work zone management systems, and travel demand management systems to accomplish TICS services. They provide operator data and command inputs to direct systems' operations to varying degrees depending on the type of system and the deployment scenario. All functionality associated with these services that might be automated in the course of TICS deployment is modelled as internal to the architecture.

6.2.7 Transport Inspection

This actor represents the human entities or systems which perform regulatory inspection of Commercial Vehicles in the field. They support the roadside inspection, weighing, and checking of credentials either through automated pre-clearance or manual methods. They form an inspection and enforcement arm of the regulatory agencies with frequent direct interface with the Commercial Vehicles and their Drivers.

6.2.8 Transport Planner

This actor represents the human entities responsible for planning, maintaining and changing the transportation network managed by the TICS. It includes organisations which are responsible for long term planning. These organisations will benefit from data collected by TICS. They may have a direct impact on the road network but can only monitor and request changes to other areas of transportation such as public transport operations, toll prices and parking lot charges, capacities, etc.

6.2.9 Traveller Information

This actor is the human entity or system that may be physically present at a traveller information service to monitor the operational status of the facility and provide human interface capabilities to travellers and other information subsystems.

6.3 Financial

This actor represents the agent types that provide payment means to the User, collect payments, and process aggregated transactions so that the Transport and Service Providers receive payment from the issuers of credit . The sub-classes of Financial actors are shown in Figure 10.

6.3.1 Clearing Operator

This actor collects and possibly aggregates transactions from one or more Service Providers or TICS for delivery to the Issuer(s) (the external class responsible for the payment system and responsible for issuing the payment means to the Traveller). The Clearing Operator can also handle the apportionment between the Service Providers and TICS. In the financial world this operator is equivalent to an Acquirer.

6.3.2 Collection Agent

This actor is responsible for selling, reloading or delivering the payment means to the Traveller and collecting the payment from the Traveller. The Collection Agent can also collect user related application specific data from the Traveller.

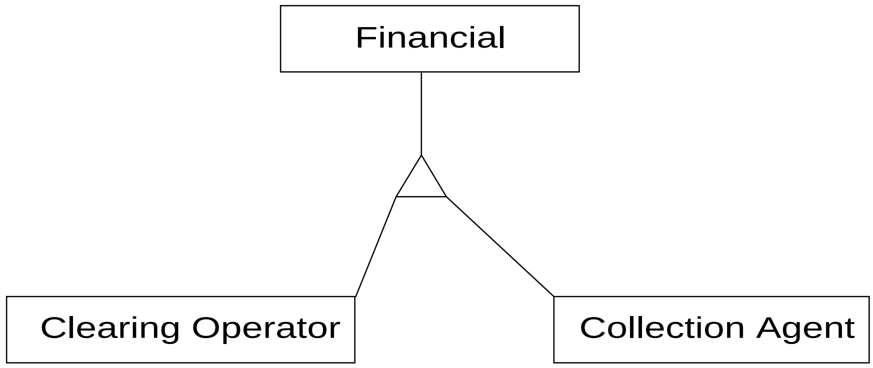

Figure 10 — The hierarchy of actors of type Financial

6.4 Infrastructure

This actor generalises the systems which provide complementary services to the road based Transport System. The subclasses of the Infrastructure actor are shown in Figure 11.

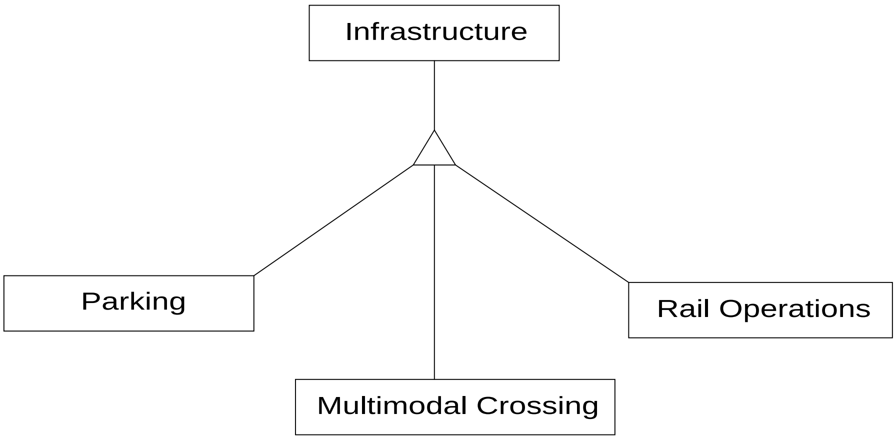

Figure 11 — Actors of type Infrastructure

6.4.1 Parking

This actor represents the human entity or system which monitors the operation of a parking station as well as the private or public organisations that provide parking lot facilities and that determine the parking lot pricing structures. This provider interfaces to TICS to coordinate parking information, such as facility location, parking availability status, applicable rates, hours of operation, and other information (security services, valet services, shuttle availability, etc).

6.4.2 Multimodal Crossing

This actor represents the equipment used by rail crossing operators to control and monitor the crossing as well as input from any non-road based transportation system that has an interference road crossing. Examples are heavy railroad, canal bridges, rivers bridges, etc. Their main characteristic is that traffic moving on them must take priority over the road traffic with which they intersect. The data provided will in its basic form be a simple “stop road traffic” indication. However more complex data flows may be provided that give the time at which priority will be required and the duration of that priority. At a rail-road crossing this would therefore be the time at which the train will arrive and the time it will take to clear the crossing. Light Rail and other specialist vehicles will be treated like other traffic at intersections, unless the operating organisation has requested priority.

6.4.3 Rail Operations

This actor is roughly the rail operational equivalent to a roadway Traffic Management Centre. It is (usually) a centralised control point for a substantial segment of a railroad’s operation. It is the source and destination of information that can be used to coordinate rail and highway traffic management. This actor would also represent a railroad’s management information system, if that system is the source or destination for this information. The multiple sources and destinations for information exchange with the railroad entity implies the need for a single, consistent interface between a given railroad’s operations for TICS traffic management. In any given implementation of TICS there may be multiple instantiations of this interface.

6.5 Information Provider/Consumer

This actor generalises the providers or consumers of information used or offered by the TICS system. The subclasses of the Information Provider actor are shown in Figure 12.

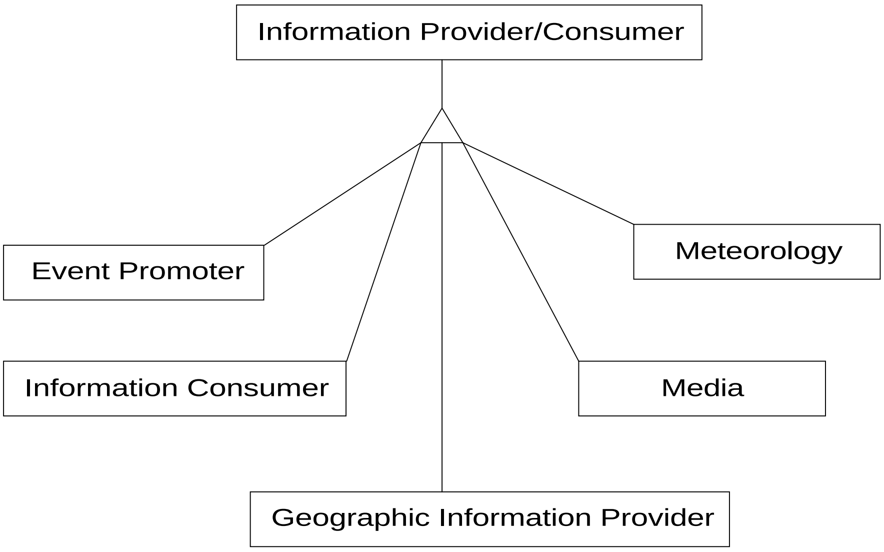

Figure 12 — Actors of type Information Provider/Consumer

6.5.1 Event Promoter

This actor represents external Special Event Sponsors that have knowledge of events that may impact travel on roadways or other modal means. Examples of such special events include sporting events, conventions, motorcades/parades, and public/political events. These promoters interface to the TICS to provide event information such as date, time, estimated duration, location, and any other information pertinent to traffic movement in the surrounding area.

6.5.2 Media

This actor represents something to which the TICS can send traffic and travel advisory information for direct output. It may be a simple output device (printer, visual display) or a system of some kind, e.g. Highway Advisory Radio in the U.S. (HAR), or the interface to a FM sub-carrier information output system. It is also the human entity from which the TICS may collect traffic flow information, incident information, special event information, or any other travel impacting events. The operator may be a TV/radio broadcaster, traffic reporting service operator, private citizens, or any other person external to the TICS.

6.5.3 Information Consumer

This actor represents the various entities that use information made available by TICS, e.g. insurance companies.

6.5.4 Meteorology

An external source of current and forecast weather conditions. This externally derived weather data is integrated with the other information and collected and disseminated by the TICS architecture to support travel planning.

6.5.5 Geographic Information Provider

This actor represents a third party developer and provider of digitised map databases used to support TICS services. It supports the provision of the databases that are required exclusively for route guidance (navigable map) as well as those that are used exclusively for display by operators and at traveller information points, e.g. kiosks (display map).

6.6 Service Provider

This actor represents the providers of external services mediated by the TICS system. The subclasses of the Service Provider actor are shown in Figure 13.

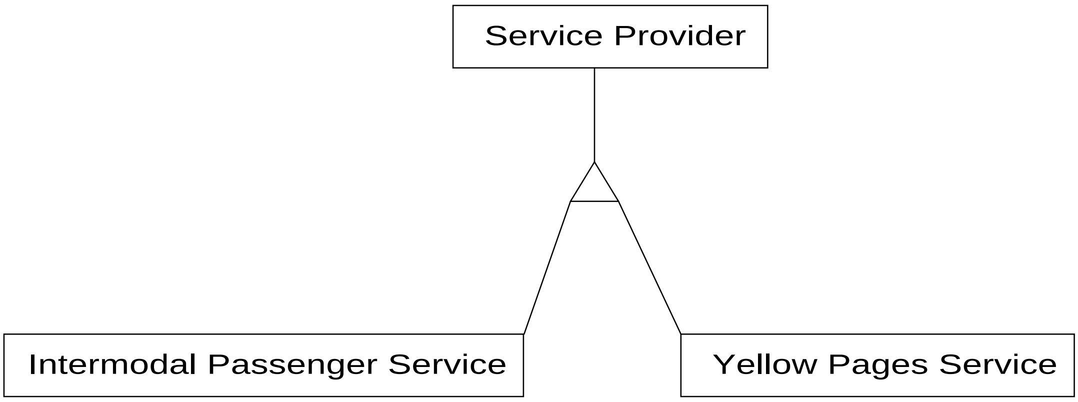

Figure 13 — Actors of type Service Provider

6.6.1 Inter-modal Passenger Service Provider

This actor provides the interface through which transportation service providers can exchange data with TICS. They are the operators of non-roadway transportation systems (e.g. airlines, ferry services, passenger carrying heavy rail). This two-way interface enables coordination for efficient movement of people across multiple transportation modes. It also enables the traveller to efficiently plan itineraries which include segments using modes not directly included in the TICS User Services.

6.6.2 Yellow Pages Service

This actor represents organisations that provide any service oriented towards the Traveller. Example services that could be included are gas, food, lodging, vehicle repair, points of interest, and recreation areas. The interface with the Service Provider is necessary so that accurate, up-to-date service information can be provided to the traveller and to support electronic reservation capabilities included in the TICS user services.

6.7 Vehicle

This actor represents the classes of vehicle that contain components of the TICS system or which are recognised in some way by the TICS system. The associated sub-classes of the Vehicle actor are shown in Figure 14.

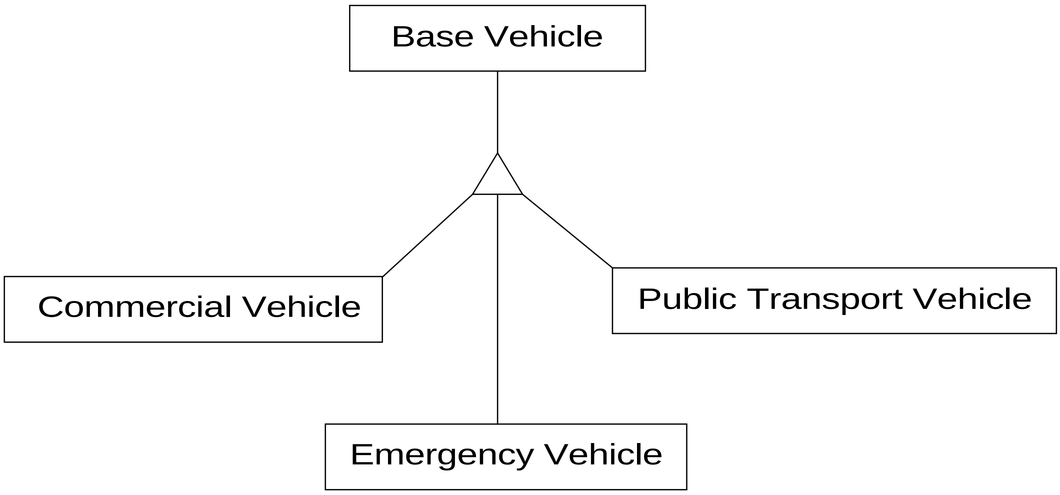

Figure 14 — The actors of type Vehicle

A distinction is made between vehicles as actors and traffic in that a Vehicle is an actor which is uniquely identified by TICS. Having been identified by TICS a vehicle can be the target of a specific message. Traffic is something which is measured by TICS but which is no way interacts with TICS, except through the actions of the drivers. Therefore traffic is not identified as an actor.

The Vehicle actor illustrates some other fine points of distinction which arise in UML modelling. Firstly the vehicle entity carries components of the TICS system. In the architecture these components are reflected in other modelling elements, particularly interface classes.

Secondly, there are other model elements (i.e. parts of the architecture) which are directly associated with the Vehicle actor. These are the control classes which form part of the automated vehicle control , and the information classes which record persistent information about individual Vehicle actors.

6.7.1 (Base) Vehicle

This actor includes any vehicle which may potentially violate traffic regulations and therby cause interaction with TICS. It also includes vehicles which are recognised for tolling, road pricing, route guidance and other TICS services. There are many actor objects of this type (e.g. ordinary cars, motor cycles and bicycles), that is they are not any the special types described below.

6.7.2 Commercial Vehicle

This actor is a subtype of vehicle with the special aspects of large commercial vehicles and vehicles designed to carry cargo that extend beyond the characteristics defined for the base Vehicle. This actor thus represents a specialisation of vehicle that is used to transport goods or services which are operated by professional drivers, typically administered as part of a larger fleet, and regulated by a Carrier Operator. This classification applies to all such vehicles ranging from small panel vans used in local pick-up and delivery services to large, multi-axle tractor trailer rigs operating on long haul routes. Certain aspects of the physical cargo are also represented by this actor.

6.7.3 Emergency Vehicle

This actor is a subtype of vehicle such as fire, ambulance and rescue vehicle. They may request traffic priority or be recognised for that purpose.

6.7.4 Public Transport Vehicle

This actor is a subtype of vehicle such as bus, light rail and taxi. They may request traffic priority or be recognised for that purpose.

7 Use Cases of the Core TICS Reference Architecture

When an actor object interacts with TICS, TICS performs a behaviourally related transaction sequence. The abstraction of similar and closely connected transaction sequences is called a **use case**. The use cases for the TICS Reference Architecture are derived top down from the TICS Fundamental Services.

The mapping of the TICS Fundamental Services to use case is shown in Table 2 and develops use case diagrams. The TICS Fundamental Services are established in ISO/TR 14813-1. The mapping is largely one to one. Variations from one to one are simple aggregations and decomposition, the latter most commonly occurring to support reuse. The most significant aggregation is for the Vehicle Status use case for which limited information is provided in the Fundamental Services.

Just as the idea of classification is natural to the modelling process, so is the grouping together of strongly related use cases. This is the basis for forming a use case diagram. This clause elaborates the use case identified in Table 2.

Table 2 —Mapping of TICS Fundamental Services to Use Cases

Fundamental Service			Use Case
Service Category	**#**	**Service Name**	
Traveller Information	1	Pre-trip Information [a]	Pre-journey Information
			Journey Payment
	2	On-trip Driver Information	On-trip Traveller Information [b]
	3	On-trip Public Transport Information	
	4	Personal Information Services	
	5	Route Guidance and Navigation [a]	Route Guidance and Navigation
			Journey Schedule
Traffic Management	6	Transportation Planning Support [a]	Transportation Planning Support
			Performance Prediction
	7	Traffic Control [a]	Traffic Control
			Traffic & Pollution Measurement & Control
			Performance Evaluation
			Performance Prediction
	8	Incident Management	Incident Management
			Traffic & Pollution Measurement & Control
	9	Demand Management	Demand Management
			Performance Prediction
	10	Policing/Enforcing Traffic Regulations	Traffic & Pollution Measurement & Control
	11	Infrastructure Maintenance Management	Infrastructure Maintenance Management
Vehicle	12	Vision Enhancement	Vehicle Status
	13	Automated Vehicle Operation	Vehicle Operation
	14	Longitudinal Collision Avoidance	Vehicle Status [c]
	15	Lateral Collision Avoidance	
	16	Safety Readiness	
	17	Pre-crash Restraint Deployment	

Fundamental Service			Use Case
Service Category	**#**	**Service Name**	
Commercial Vehicle			Order & Shipment [d]
	18	Commercial Vehicle Pre-clearance [e]	Commercial Vehicle Tour Planning
			Route Guidance and Navigation
			Journey Payment
	19	Commercial Vehicle Administrative Processes	Commercial Vehicle Administrative Processes
	20	Automated Roadside Safety Inspection	Commercial Vehicle Road Operation [f]
	21	Commercial Vehicle On-board Safety Monitoring	
	22	Commercial Vehicle Fleet Management	
Public Transport	23	Public Transport Management	Route & Schedule Planning
			Fixed Route Public Transport [g]
	24	Demand Responsive Transport Management	Demand Responsive Public Transport
	25	Shared Transport Management	Journey Schedule
Emergency	26	Emergency Notification and Personal Security	Emergency Notification and Personal Security
	27	Emergency Vehicle Management [e]	Emergency Resources Allocation
			Emergency Vehicle Management
	28	Hazardous Materials and Incident Notification	Incident Management
Electronic Payment	29	Electronic Financial Transactions [e]	Payment Means
			Fare Collection
			Vehicle Charges
			Payment Transaction
Safety	30	Public Travel Security	Emergency Notification and Personal Security
			Vehicle Status
	31	Safety Enhancement for Vulnerable Road Users	Safety Enhancement for Vulnerable Road Users
	32	Intelligent Junctions and Links	Vehicle Status

Table Footnotes:

a. Service divided to support reuse.

b. The services are provided through different interfaces but are inherently the same.

c. The services are not defined sufficiently to identify individual use case.

d. Defined subsequently to Fundamental Services.

e. Service divided to support reuse.

f. Services are aggregated because of overlap in supporting operations.

g. Separate operational from planning.

7.1 Traveller Information Use Case Diagram

These transaction sequences cover journey planning and confirmation, route guidance and yellow pages information and services. The Traveller Information diagram (Figure 15) contains the following use cases.

There is an implicit role for a Location Data Source actor in association with both Traveller and Driver actors in Figure 15.

7.1.1 Pre-Journey Information

These transactions produce a journey plan to meet the requirements of a traveller's journey request. The Traveller actor initiates the request and receives traveller information. Facilities are also provided for subsequent trip confirmation and to enable the Traveller to make advanced payments. The journey plan can be multi-modal (more than one trip) and is generated using the facilities provided by the Route Guidance and Navigation use case. It may also include demand responsive public transport services, ride-sharing, and the use of services from inter-modal transportation service providers such as heavy rail, airlines, etc.

The Traveller Information actor can be an intermediary for the Traveller.

7.1.2 Journey Payment

These transactions provide for trip confirmation and enable the traveller to make advanced payments. They provide payment for each segment (trip) of a pre-planned journey. The Traveller actor must provide the means of payment at the Travel Terminal interface.

7.1.3 On-Trip Traveller Information

These transactions provide Travellers with access to transport running data, route guidance, and data about general services (Yellow Pages Service actor), weather information (Meteorology actor) and tourist information (Media actor). They enable Travellers to make reservations and payments for these services. Data about services is obtained from Yellow Pages Services who have registered and made their contact details available. Access to running data may cause a revision of journey planning as in Pre-Journey Information.

7.1.4 Route Guidance and Navigation

These transactions provide advisory information and route guidance and navigation for Travellers and Drivers. In addition they support journey planning for Travellers. Travellers and Drivers provide route parameters. Multi-modal journeys are scheduled for Travellers for both on-line personal traveller guidance and for journey planning. Centralised route determination facilities are provided for in-vehicle dynamic guidance, or for generating link travel times to be used in autonomous guidance. Vehicle routes are also provided for commercial vehicle route planning and for emergency vehicles dispatched in response to incidents. There is a strong spatial component to planning, relevant data being provided through the Geographic Information Provider actor. Regular updates are also provided by Meteorology.

7.1.5 Journey Schedule

These transactions confirm that all the segments (trips) of a journey route can be serviced, and they generate the collective schedule. They make use of regular public transport services as well as advanced public transport. Reservations for non-TICS modes are negotiated with the Intermodal Passenger Service actor.

7.1.6 Demand Responsive Public Transport

(see 7.5.3)

7.2 Traffic Management Use Case Diagram

These transaction sequences cover the range of traffic control and traffic management operations supported by TICS. The Traffic Management diagram (Figure 16) contains the following use cases.

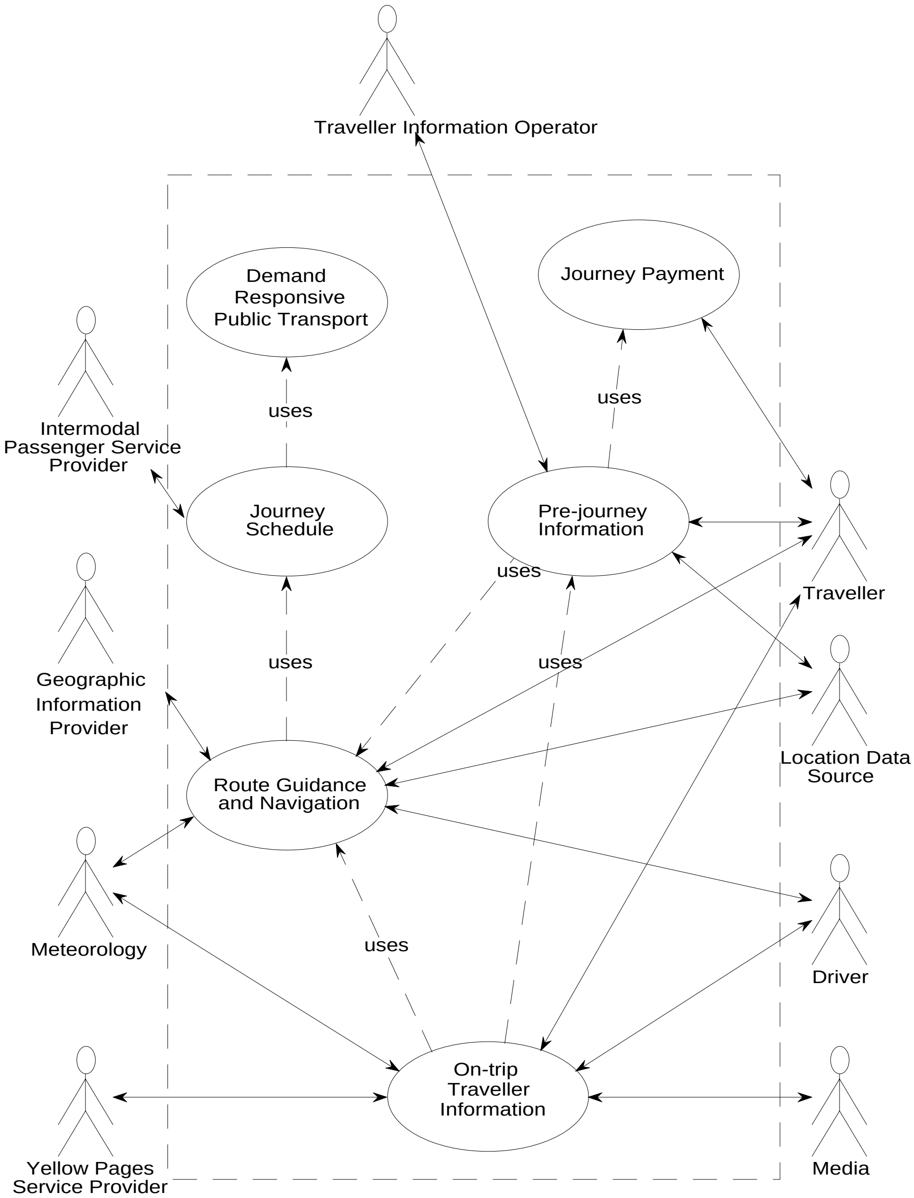

Figure 15 — Traveller information Use Case diagram

7.2.1 Transportation Planning Support

This is a Transport Planner operator driven analysis of performance of the traffic and public transport network in order to develop enhancements. Facilities are provided for the import of operational data to analysis modules. Data can be evaluated to find any changes that could improve network operational efficiency. The revised network model can be tested with operational data to check on the effect of any proposed changes. Accepted revised network data is sent to TICS modules. The network model can be revised for jurisdictional policy changes and effects tested before implementation. Data about the current or new road and freeway network can be documented.

7.2.2 Performance Prediction

These transactions process the data from some use case to generate a predictive model of network operation for use by other use case. The predictive model can use long term data and data from adjacent Roadway Groups (see ISO/TR 14813 Part 3). Traffic Operators can display predicted data. Prediction data is exchanged between Roadway Groups.

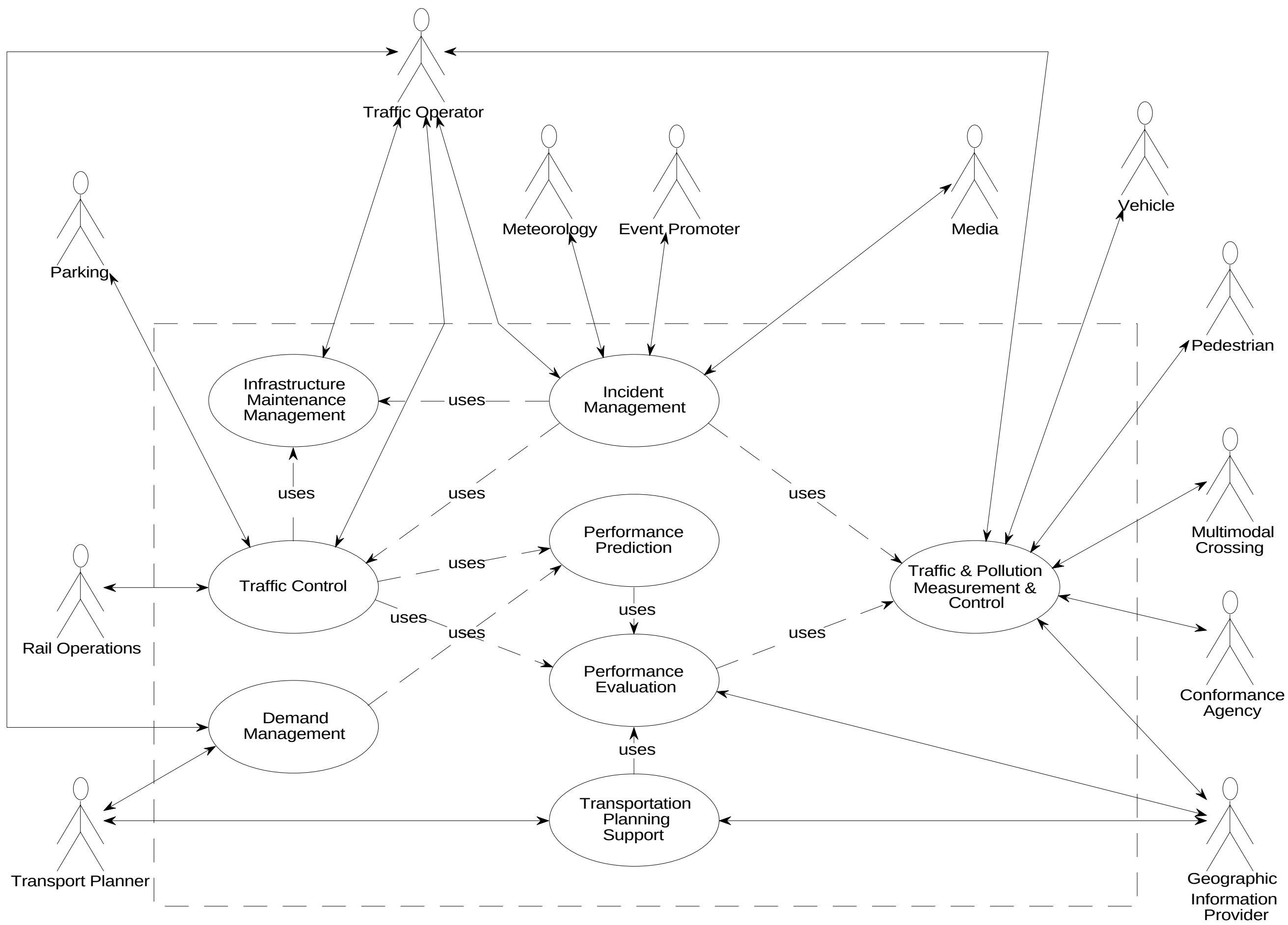

Figure 16 — Traffic management use case diagram

7.2.3 Traffic Control

This is an ongoing interaction with traffic through the Roadside Peripherals (signals and other signs) which communicate control information and guidance to Drivers. Traffic control strategy depends on current traffic conditions and default strategy. Traffic control strategy can be overridden by other use case. Traffic control strategy can be overridden by a Traffic Operator actor.

Coordination of control outputs can be based on a range of algorithms using real time data. Local Control Groups (see Part 3) can operate using local data with no coordination. Parking and Traffic Operator (construction and maintenance) actors may be given instructions.

7.2.4 Traffic & Pollution Measurement & Control

These transactions process and store traffic data collected through sensors (inputs are sensed from traffic, Multi-modal Crossing, Pedestrian, etc) for use in Traffic Control, and other use case. There is a strong spatial component to measurement and modelling, relevant data being provided through the Geographic Information Provider actor.

Collected data is integrated to form current and long term (historic) data attributes. Many use case access the current and long term attributes as a source of traffic data. Traffic Operators can display current and long term attributes. Media operators can also display data and send some for output by the media system.

7.2.5 Performance Evaluation

These transactions retrieve all the available data pertinent to traffic in the roadway network and analyse it in order to develop a range of attributes used in computing traffic control strategies. There is a strong spatial component to measurement and modelling, relevant data being provided through the Geographic Information Provider actor.

7.2.6 Incident Management

This is based on an ongoing analysis of traffic data to look for indications of possible incidents. Input is accepted from a number of actors (Traffic Operator, Event Promoter, Rail Operations, Media, and Meteorology).

Sensor data is analysed for indications of possible incidents (taking data developed by the Traffic and Pollution Measurement & Control use case). Location of possible incidents is fixed by a location data source and incidents are classified into the categories of possible, predicted and current.

Possible incidents are reviewed for transfer to predicted category if confidence level is high enough. Predicted incidents are reviewed for transfer to current category when start time occurs.

Traffic Operators can review and amend incident data. Current incidents are automatically cleared when their duration has expired. Incident data is exchanged between Roadway Groups (Part 3).

7.2.7 Demand Management

These transactions predict and manage travel demand to make the most efficient use of the roadway and other parts of the transportation network served by the function. Demand management is based on policy data and the operational data provided by Traffic Control and other use case.

Policy data is set up by the Transport Planner actor. Policy may be overridden by the Traffic Operator actor. Demand forecast results are implemented by other use case.

7.2.8 Infrastructure Maintenance Management

These transactions manage the road, communications and computer infrastructure. There is interaction with the Traffic Operator actors responsible for this area. These actors schedule road works and highway maintenance and notify TICS of the associated incidents. Traffic data is used to plan works so as to minimise disruption.

7.3 Vehicle Use Case Diagram

These transaction sequences cover all automated vehicle operation both in-vehicle and automated highway. The Vehicle diagram (Figure 17) contains the following use cases.

7.3.1 Vehicle Status

These transactions monitor the Vehicle actor's operation, and roadway conditions plus the vehicle's position and motion relative to surrounding objects. This data is used to provide status information to other processes and use cases plus the warning messages for output to the Driver. If the Vehicle is fitted with automatic control equipment, the data produced by these processes can be used to initiate corrective action.

7.3.2 Vehicle Operation

These transactions allow a Vehicle actor to be automatically controlled. The processes are structured so that various levels of control may be provided, starting with a simple driving aid for cruise control. The highest level of automatic control provided is that which can be used in conjunction with road and freeway lanes equipped for automated highway operation. The Driver requests the operational mode. The Vehicle is an implicit actor under control of the use case transactions.

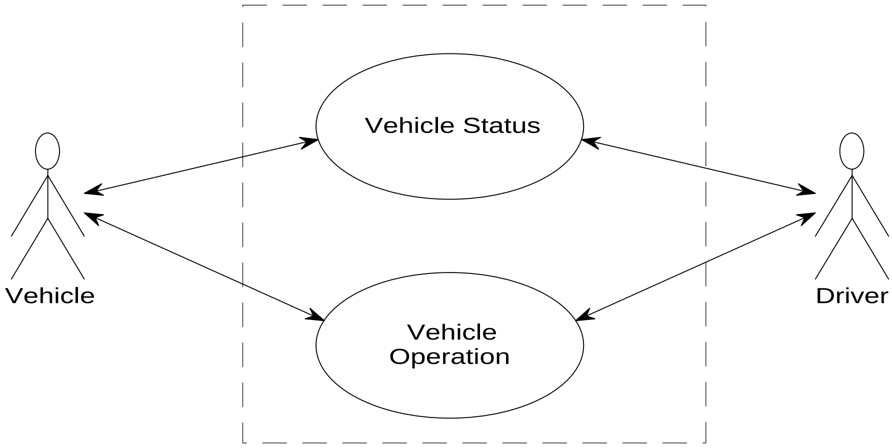

Figure 17 — Vehicle use case diagram

7.4 Commercial Vehicle Use Case Diagram

These transaction sequences cover commercial vehicle and goods transportation activities which involve global information stored and accessed by TICS. The Commercial Vehicle diagram (Figure 18) contains the following use cases.

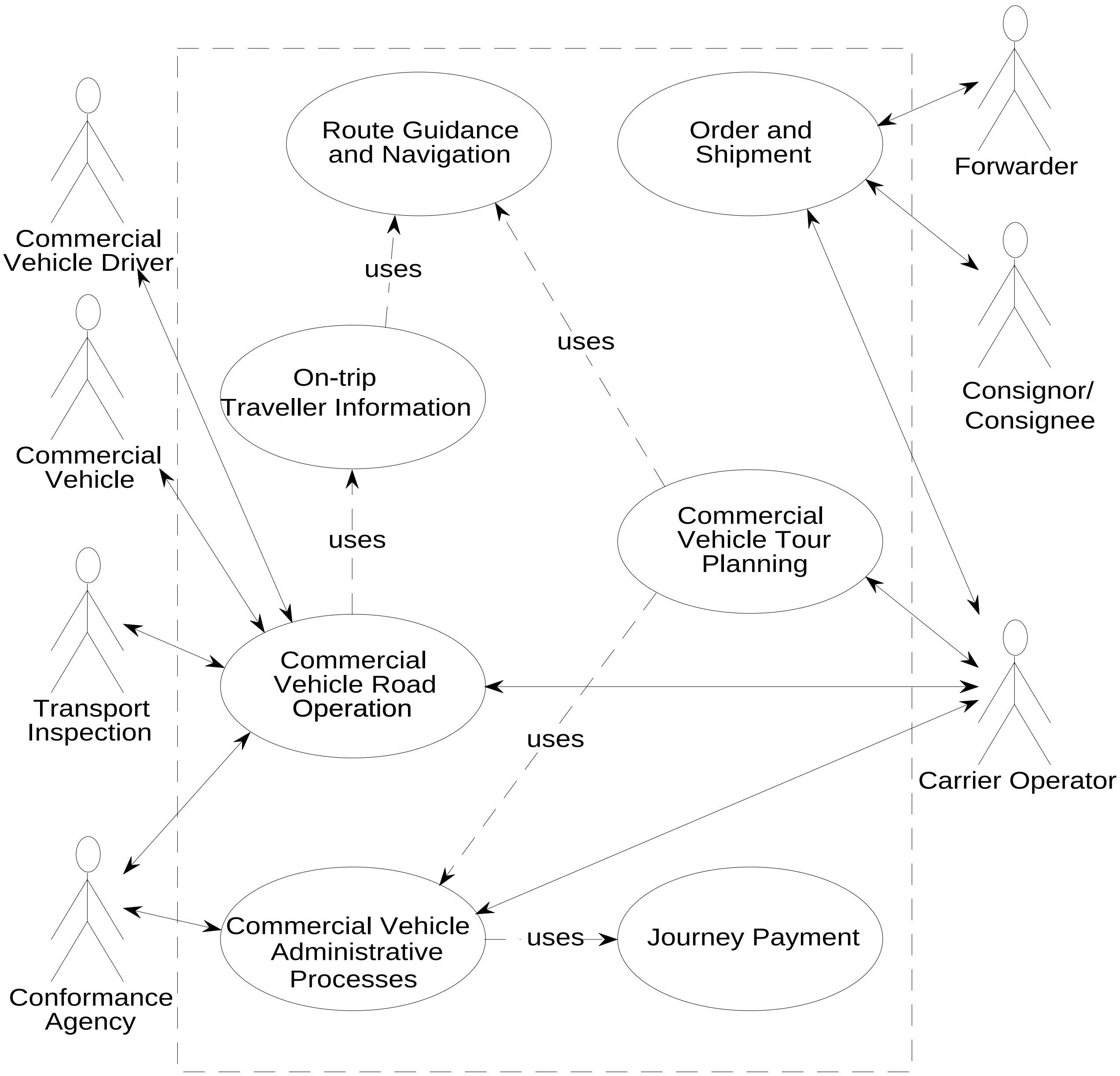

Figure 18 — Commercial Vehicle use case diagram

7.4.1 Order and Shipment

These transactions maintain the TICS information about a shipment from the time of the order by the consignor to the reception of goods by the consignee. The key TICS transactions are to provide registers of service providers and to enable the goods to be tracked throughout intermodal journeys. The Consignor can select a Forwarder from an on-line register. The Forwarder logs and updates the journey information for the Goods Item so that tracing can be supported. This includes Carrier data.

7.4.2 Commercial Vehicle Tour Planning

These transactions plan commercial vehicle freight complements and routes taking into account the needs of this type of vehicle, as well as the electronic credential and tax filing needed to use the route. The Carrier Operator actor does the route planning using the Route Guidance and Navigation use case.

7.4.3 Commercial Vehicle Administrative Processes

These transactions support Commercial Vehicle Tour Planning and provide the interactions with the Conformance Manager actors so that a Commercial Vehicle tour can be approved. Having decided on a route, a designated vehicle can be pre-cleared through the roadside check facilities so that it does not have to stop. The Carrier Operator provides identification of Vehicle and Driver. The Conformance Agency actor provides checks on the worthiness of the actors to be involved in the Tour.

The details of the required credentials and tax filing are provided from the appropriate Conformance Agencies. The log of operations at the roadside facilities is also analysed so that details of Vehicles, Carrier Operators and Drivers failing checks can be used in clearance. Clearance data is recorded so that vehicles on the roadway can pass the screening checks.

The associated tour information is recorded for subsequent use at roadside checking stations.

7.4.4 Commercial Vehicle Road Operation

These transactions clear Commercial Vehicles through screening and border crossing checks and carry-out safety checks. If the vehicle is not pre-cleared, or it fails its safety checks the Driver will be requested to pull into the roadside facility. The Roadside Inspection Operator may override the decision to pull-in (or not) and may also select manual pull-in. Details of those Vehicles with safety problems are sent to all roadside facilities to highlight the need for future safety checks. Violation actions are initiated. The Carrier Operator can deliver routing and delivery instructions for the Driver and monitor the Vehicle and cargo.

The Driver uses the use case On-Trip Traveller Information to obtain route guidance and other in formation.

7.4.5 Route Guidance and Navigation

(see 7.1.4)

7.4.6 Journey Payment

(see 7.1.2)

7.4.7 On-Trip Traveller Information

(see 7.1.3)

7.5 Public Transport Diagram

These transaction sequences cover the scheduling, dispatching, operation and booking of public transport services. The Public Transport use case diagram (Figure 19) contains the following use cases.

7.5.1 Route & Schedule Planning

These transactions manage the route planning and scheduling of fixed and variable route public transport services. The generation of new regular public transport routes and schedules is done at the request of the Public Transport Operator and takes into account the operational data plus input from a variety of other sources. New schedules can be generated separately from routes, and can be produced in response to inputs from parking lots if a change to the current park and ride service is needed. The new routes and services are made available to this and other use cases, and automatically published to Travellers. There is a strong spatial component to planning, relevant data being provided through the Geographic Information Provider actor.

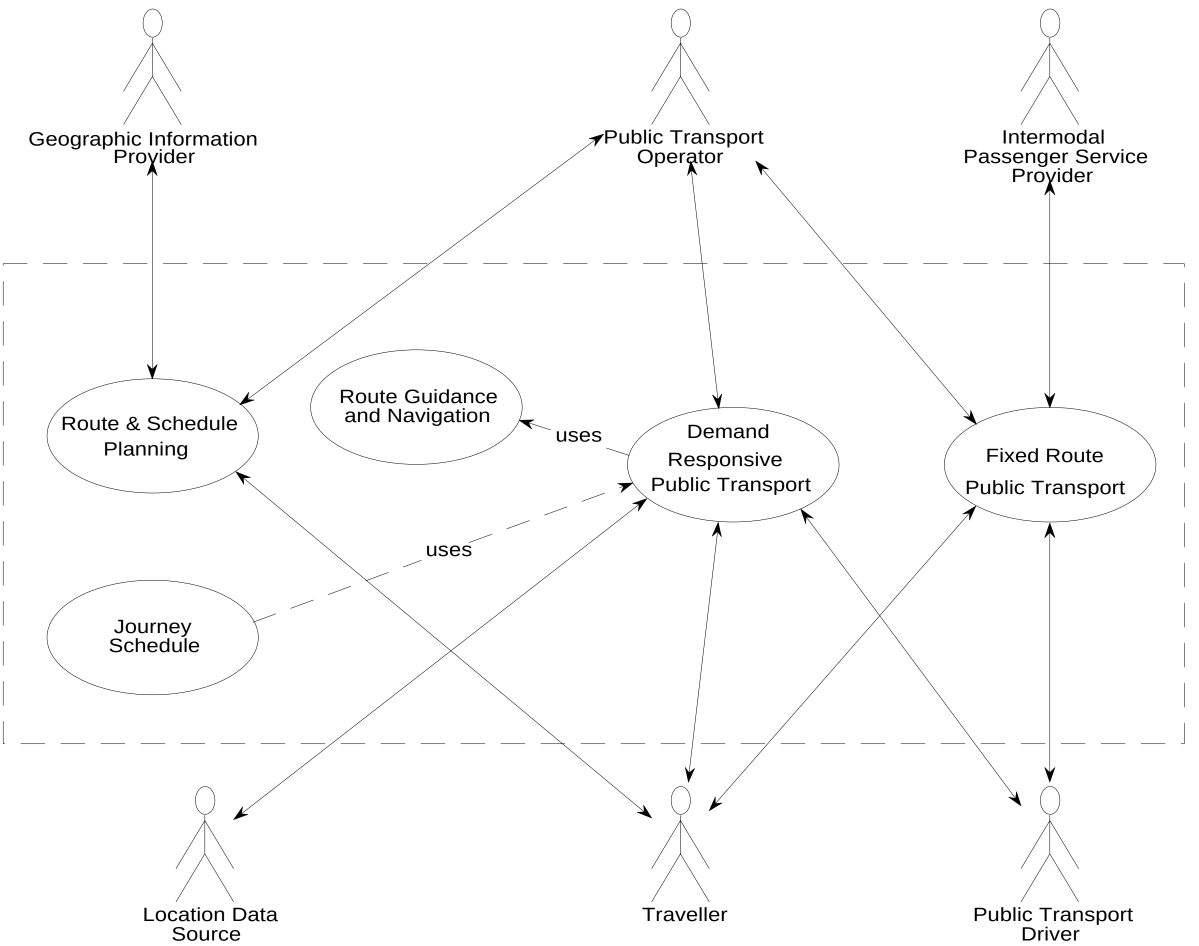

Figure 19 — Public Transport use case diagram

7.5.2 Fixed Route Public Transport

These transactions provide information on the current state of operation of public transport vehicles, and how they are performing against the schedules. The processes are responsible for keeping vehicles on schedule and taking action to get them back on schedule when any deviations are found. Instructions will be sent to the vehicle driver(s) and vehicle priority requested through the Traffic Control use case. The Traveller can query the operating schedules. Intermodal Passenger Services can update information pertinent to connections. The Public Transport Operator can do manual overrides.

7.5.3 Demand Responsive Public Transport

These transactions schedule and dispatch demand responsive public transport services in response to requests from the Journey Schedule use case. The services will be personalised to suit the Traveller's request. The Operator can do manual dispatching. The Traveller can get information on ride availability etc. The Driver receives itinerary instructions and possibly route guidance (Route Guidance and Navigation). The vehicle gets positioning information from a Location Data Source.

7.5.4 Journey Schedule

(see 7.1.5)

7.5.5 Route Guidance and Navigation

(see 7.1.4)

7.6 Emergency Use Case Diagram

These transaction sequences cover emergency operations stemming from roadway incidents or security violations. The Emergency diagram (Figure 20) contains the following use cases.

7.6.1 Emergency Notification & Personal Security

These transactions notify an emergency which occurs on-board a vehicle or within a public transport facility, or on other parts of the roadway network. Notification can be initiated by a Driver or automatically, and thus involve any Traveller in an area with surveillance. Mobile situations are located using a Location Data Source.

7.6.2 Emergency Resources Allocation

These transactions allocate emergency services in response to requests received from a range of inputs. The basis for the allocation process is predefined criteria, which the emergency services operator has the facility to set up and override. If there are no criteria to fit an emergency, then the Emergency Services Operator is requested to provide the required allocation. The Traveller can initiate an emergency message and receive acknowledgement. There is a strong spatial component to planning, relevant data being provided through the Geographic Information Provider actor.

7.6.3 Emergency Vehicle Management

These transactions communicate with and support the Emergency Vehicle Driver in the incident/emergency to which the response is being directed. The Driver may use Route Guidance and Navigation. Once at the location, the Emergency Vehicle Driver can report back with updates on the progress being made with the emergency response. The Emergency Operator is provided with information and the Emergency Vehicle is tracked using a Location Data Source. There is a strong spatial component to planning, relevant data being provided through the Geographic Information Provider actor.

7.6.4 Route Guidance and Navigation

(see 7.1.4)

7.7 Electronic Payment Use Case Diagram

These transaction sequences cover fee collection systems concerning vehicle related transport services such as toll, parking and route guidance as well as fare collection and advanced payments for a wide range of services. The Electronic Payment diagram (Figure 21) contains the following use cases.

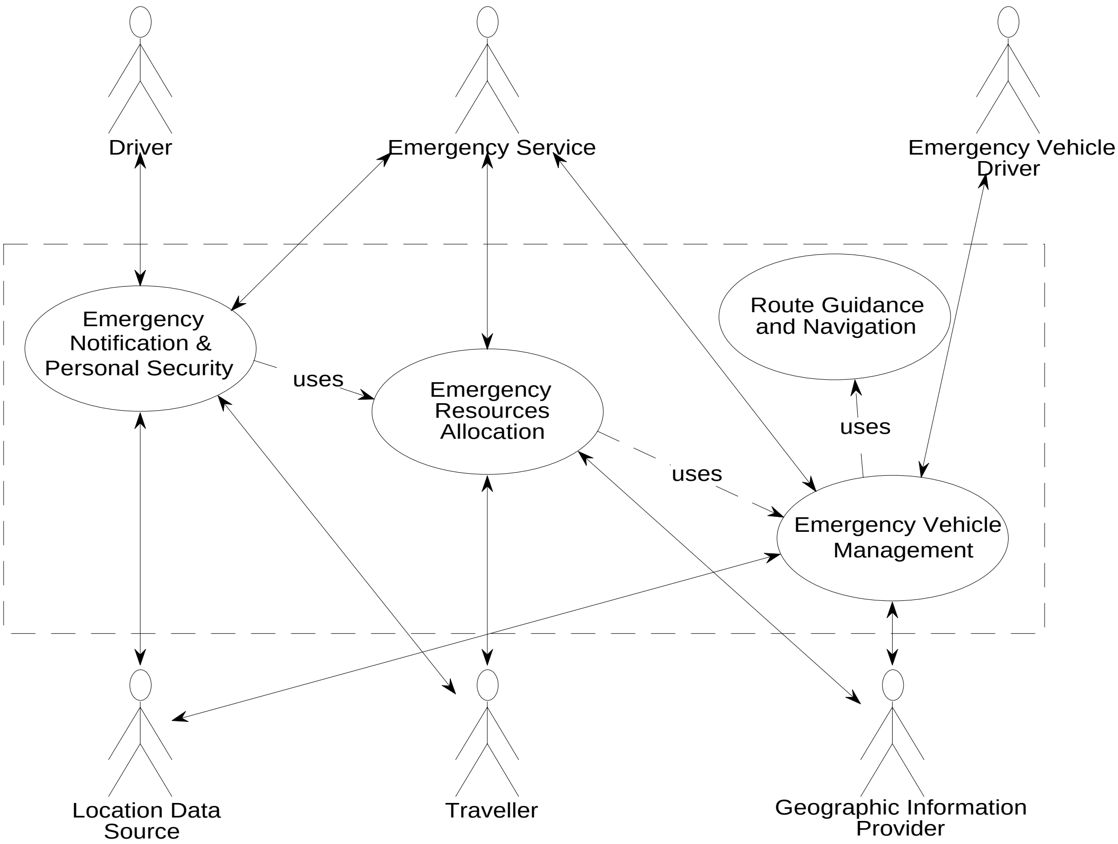

Figure 20 — Emergency use case diagram

7.7.1 Payment Means

This transaction captures the expression of a contract between the Traveller and the external Issuer via a Collection Agent that allows the Traveller to access the services available in the payment system, e.g. an account in a credit card system or an electronic purse. The Collection Agent transacts the credit to an electronic purse used by a Traveller. A Clearing Operator receives registration of a credit payment means for a Traveller from the Resource (see Part 3) to be used.

7.7.2 Fare Collection

These transactions collect fares from public transport users on-board a public transport vehicle, for the use of current public transport services, and advanced payments for public transport services and for other (yellow pages) services. They use the Payment Transaction use case. The Traveller must provide the payment instrument.

7.7.3 Vehicle Charges

These transactions provide facilities for the electronic fee collection from vehicles as they pass through roadside collection points. They use the Payment Transaction use case. The Vehicle is sensed by a Roadside Peripheral and must carry a payment instrument.

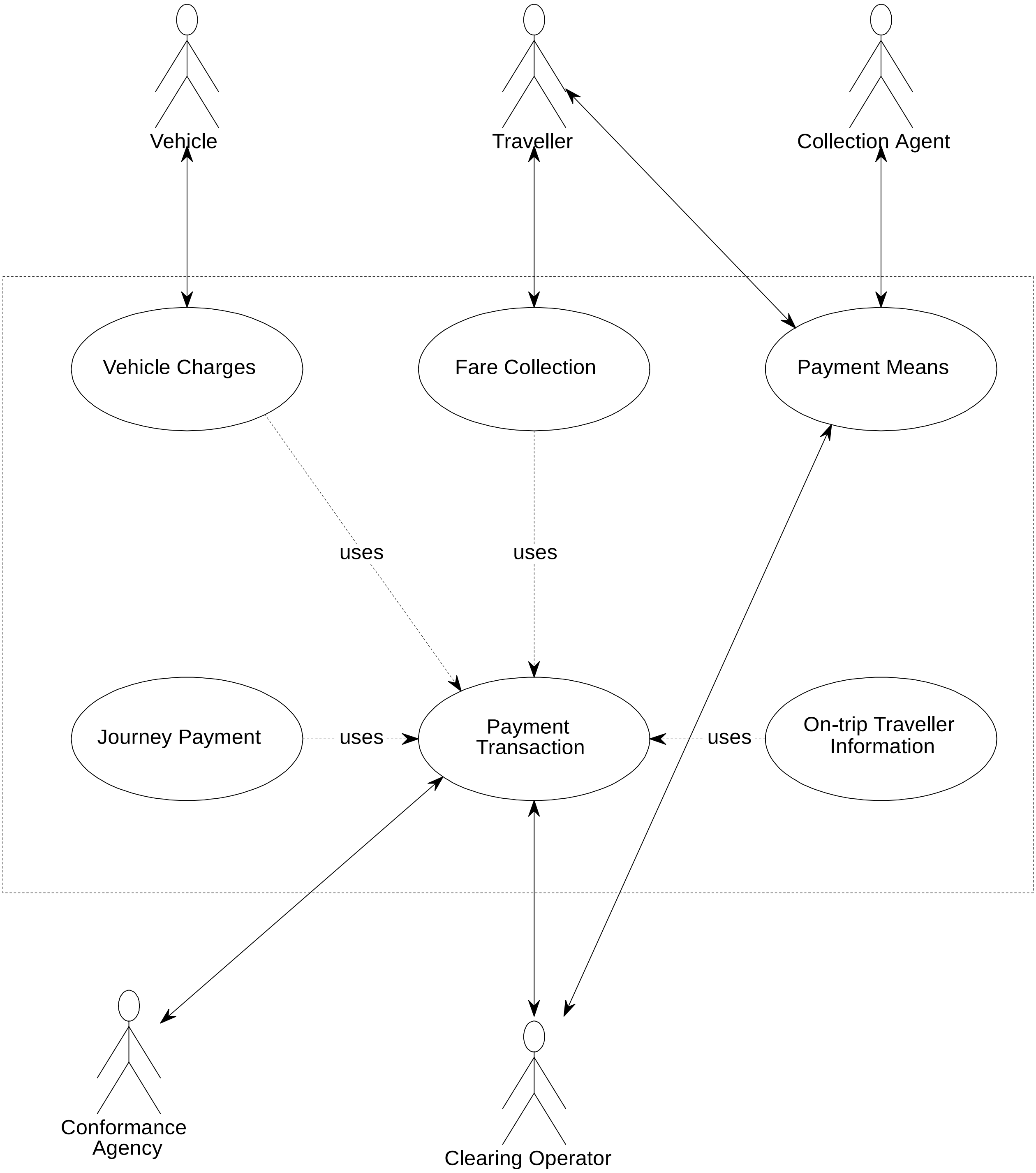

Figure 21 — Electronic Payment use case diagram

7.7.4 Payment Transaction

These transactions maintain a centralised store of data on the prices (tariff) being charged for tolls, spaces at parking lots and fares. They enable Drivers and Travellers to pay for tolls, fares and parking lot charges, plus other (yellow pages) services and in the case of Travellers, as part of their journey planning facilities. Advance payment is supported.

7.7.5 Journey Payment

(see 7.1.2)

7.7.6 On-Trip Traveller Information

(see 7.1.3)

7.8 Safety Use Case Diagram

These transaction sequences cover automated safety services. The Safety diagram (Figure 22) contains the following use cases.

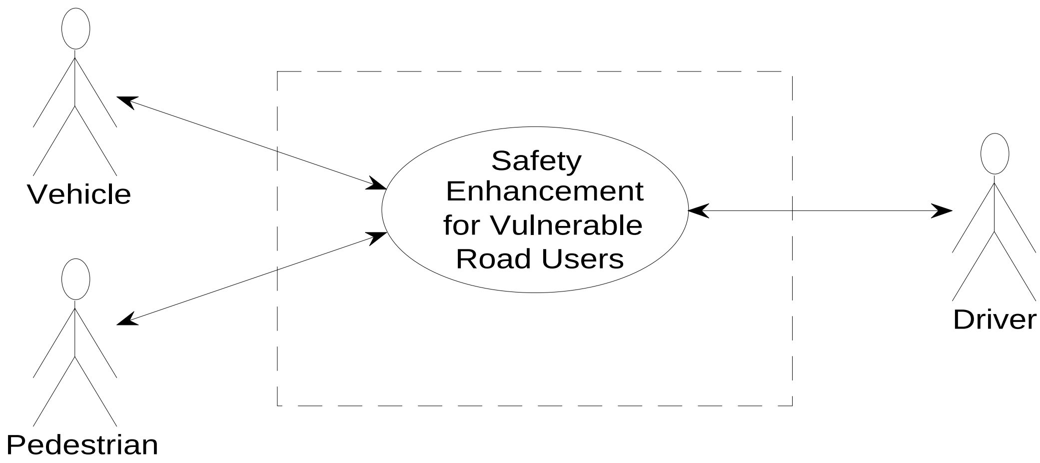

Figure 22 — Safety use case diagram

7.8.1 Safety Enhancement for Vulnerable Road Users

These transactions cover the application of TICS technologies to the enhancement of safety levels for vulnerable road user groups. These groups include: motor cyclists, pedal cyclists, pedestrians and all vehicles in vulnerable situations. Safety enhancement measures may include: smart pedestrian crossings, speed warning systems, vehicle presence detection. Pedestrians and Vehicles are sensed automatically, and associated Drivers and Pedestrians are warned.

7.9 Actor/Use Case Matrix

This matrix lists the Actor name, followed by Use Cases in which these actors are involved.

Operator Carrier

- Commercial Vehicle Administrative Processes
- Commercial Vehicle Road Operation
- Commercial Vehicle Tour Planning
- Order and Shipment

Clearing Operator

- Payment Means
- Payment Transaction

Collection Agent

- Payment Means

Commercial Vehicle

- Commercial Vehicle Road Operation

Commercial Vehicle Driver

- Commercial Vehicle Road Operation

Conformance Agency

- Commercial Vehicle Administrative Processes
- Commercial Vehicle Road Operation
- Payment Transaction
- Traffic & Pollution Measurement & Control

Consignor/Consignee

- Order and Shipment

Driver

- Commercial Vehicle Road Operation
- Demand Responsive Public Transport
- Emergency Notification and Personal Security
- Emergency Vehicle Management
- Fixed Route Public Transport
- On-trip Traveller Information
- Route Guidance and Navigation
- Safety Enhancement for Vulnerable Road Users
- Vehicle Operation
- Vehicle Status

Emergency Service

- Emergency Notification and Personal Security
- Emergency Resources Allocation
- Emergency Vehicle Management

Emergency Vehicle Driver

- Emergency Vehicle Management

Event Promoter

- Incident Management

Forwarder

- Order and Shipment

Geographic Information Provider

- Emergency Resources Allocation
- Emergency Vehicle Management
- Performance Evaluation
- Route & Schedule Planning
- Route Guidance and Navigation
- Traffic & Pollution Measurement & Control
- Transportation Planning Support

Intermodal Passenger Service Provider

- Fixed Route Public Transport
- Journey Schedule

Location Data Source

- Demand Responsive Public Transport
- Emergency Notification and Personal Security
- Emergency Vehicle Management
- Pre-trip Information
- Route Guidance and Navigation

Media

- Incident Management
- On-trip Traveller Information

Meteorology

- Incident Management
- On-trip Traveller Information
- Route Guidance and Navigation

Multimodal Crossing

- Traffic & Pollution Measurement & Control

Parking

- Traffic Control

Pedestrian

- Safety Enhancement for Vulnerable Road Users
- Traffic & Pollution Measurement & Control

Public Transport Driver

- Demand Responsive Public Transport
- Fixed Route Public Transport

Public Transport Operator

- Demand Responsive Public Transport
- Fixed Route Public Transport
- Route & Schedule Planning

Rail Operations

- Traffic Control

Traffic Operator

- Demand Management
- Incident Management
- Infrastructure Maintenance Management
- Traffic & Pollution Measurement & Control

- Traffic Control

Transport Inspection

- Commercial Vehicle Road Operation

Transport Planner

- Demand Management
- Transportation Planning Support

Traveller

- Demand Responsive Public Transport
- Emergency Notification and Personal Security
- Emergency Resources Allocation
- Fare Collection
- Fixed Route Public Transport
- Journey Payment
- On-trip Traveller Information
- Payment Means
- Pre-journey Information
- Route & Schedule Planning
- Route Guidance and Navigation

Traveller Information

- Pre-journey Information

Vehicle

- Safety Enhancement for Vulnerable Road Users
- Traffic & Pollution Measurement & Control
- Traffic Control
- Vehicle Charges
- Vehicle Operation
- Vehicle Status

Yellow Pages Service Provider

- On-trip Traveller Information

8 Sequence Diagrams

Sequence diagrams document the use case in a formal way. In this clause a set of sequence diagrams corresponding to the use case diagrams of Clause 7 are defined. In the process the top level packages identified in 5.3 (i.e. Roadway, Transport, Vehicles, Events, Payment) are populated with some abstract classes.

In general, packages are populated by a number of related classes that deliver the functionality of the package. A package is then a convenient abbreviation for a cohesive set of functionality that also has a rationale in modularity[5]. Thus, as shown in Annex A, the development of class, package and sequences diagrams is highly interrelated.

TICS reference architecture – Part 4 (ISO/TR 14813-4) describes the main characteristics of a class.

- A class is materialised in objects that conform to the class specification. That specification defines the interface for each object.
- Objects interact through the operations advertised in their interface.
- Objects store data. The current data is called the state of the object.
- One object can send a message to another object (belonging to any class) thereby invoking one of its operations. The message has two effects. Firstly it may cause a change in the state of the target object. Secondly the initiator object may receive a response.

Thus the classes define the engine that delivers the functionality specified in the use cases.

In this clause one abstract class of objects is defined for each package. The classes within the packages are then related to the transactions of the use case specified in Clause 7 by identifying the operations required of these abstract classes. (The attributes required to maintain the associated state will be treated as implicit. Many of these will arise in associated information classes that will be defined in ISO/TR 14813 Part 3.)

The use of one class per package is sufficient to define the core architecture. In Part 3 the core architecture is elaborated and each of these abstract classes is transformed into more concrete classes. In so doing the operations are more finely partitioned. The aim at this stage is to focus on the abstract operations and interactions which are required to support the use case. Thus the core architecture is completed by defining the dynamic component in the form of sequence diagrams.

Because of the unique association, each class is named after its owner package (e.g. Vehicle Class within the Vehicles Package). The full complement of packages and classes is shown in Figure 23. The packages can be usefully described in two sets, the control and information packages and their classes on the left of Figure 23, and the interface packages and their classes on the right. The control and information classes and their interactions realise the functionality of the TICS Reference Architecture. The interface classes support transactions with the actors across the architecture boundary. The class diagrams in this clause present the operations of the dynamic architecture, in correspondence with the use case diagrams.

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[5] Note: The UML package model can be developed by recursive decomposition, but there is little point in pursuing this development path on its own. The reason is that packages only define the static architecture. A dynamic architecture is also necessary.

8.1 Traveller Information

This clause develops the class operations and interactions into a sequence diagram which describes the logical flows underlying the Traveller Information Use Case diagram.

8.1.1 Class Operations for Traveller Information

The operations of the abstract classes associated with the Traveller Information Use Case Diagram (Figure 15) are shown in Figure 24. These operations include:

Roadway Class

- access roadway conditions: This operation interrogates the relevant predicted and current data on the operation of the roadway, according to the parameters of the enquiry.

Transport Class

- establish journey conditions and options: This operation can be invoked by a travel terminal interface object to transmit the journey specification from a Traveller actor or other actor, and return current options and associated data.

- operator access: This operation can be invoked by an operating interface object to support the maintenance of traveller information databases (information classes) by different types of actors.

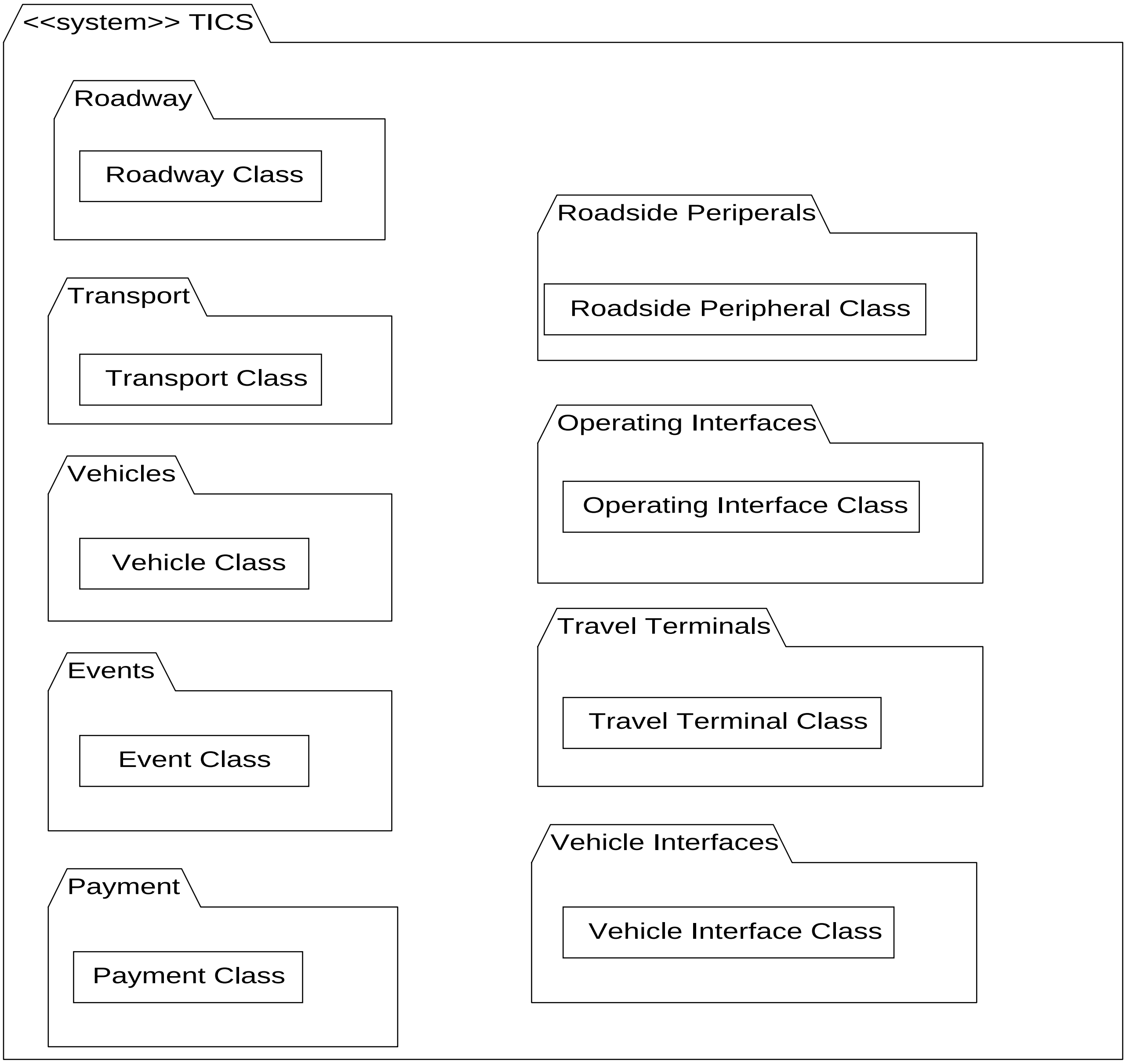

Figure 23 — Packages and their abstract classes

- route guidance: This operation can be invoked in numerous journey planning situations and performs detailed option planning covering different transport means and the roadway network; it will make dynamic checks on available capacity.

- schedule journey: This operation implements a journey plan using the data developed by operations such as route guidance; it obtains the necessary commitments for service and provides confirmation.

Event Class

- access incidents: This operation returns incident data according to the parameters of the enquiry.

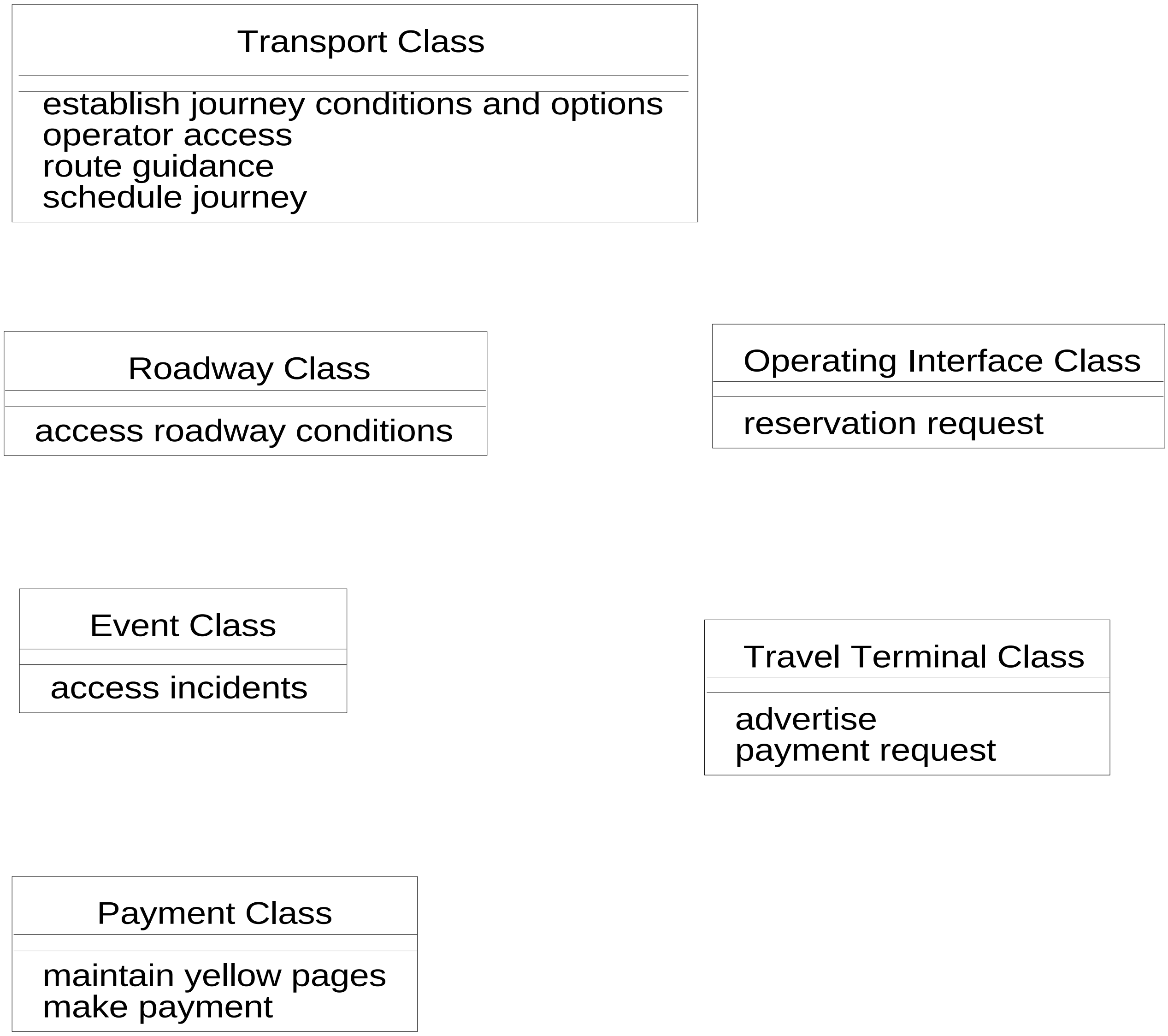

Figure 24 — Operations of the abstract classes relevant to the Traveller Information object interactions in Figure 25

Payment Class

- maintain yellow pages: This operation supports a Yellow Pages Service actor through an operator interface object in order to gain permission to advertise and to maintain their yellow pages information in a TICS database (information classes).

- make payment: This operation implements payment for service; it requires the payment means to be identified as input, it accesses an established billing record if it is a post service payment, it accesses data on tariffs, it prepares records for subsequent financial transactions with clearing agent actors.

Operating Interface Class

- reservation request: This operation supports the interaction with actors such as Geographic Information Providers, Intermodal Passenger Services or Yellow Pages Services so that booking and confirmation can be obtained for a relevant trip in a journey etc.

Travel Terminal Class

- advertise: This operation is executed to provide relevant data to a travel terminal about yellow pages service; thus it may involve filtering by location and other searches to address individual Traveller actor needs.

- payment request: This operation performs an interaction with a Traveller actor to obtain a payment means and then pass this data on to the Payment class.

8.1.2 Traveller Information Sequence Diagram

The logic of the Traveller Information transactions is described in the sequence diagram of Figure 25.

The use cases Pre-Journey Information, Route Guidance and Navigation, Journey Schedule and Journey Payment form a natural sequence, as shown in Figure 25 down its left-hand side. A major portion of these transactions is served by operations of the Transport Class, as shown in the approximate centre of the sequence diagram. Journey Schedule uses the Demand Responsive Public Transport use case which occurs in 8.5.

The Transport class is dependent on the Roadway class for roadway conditions information. The Transport class is also dependent on the Payment class to process payments. It is also dependent on the Event class to access incident data.

The remaining use case, On-trip Traveller Information, is centred on the Payment class for operations which maintain the advertisement database, make reservations and payment. It also makes use of the Pre-Journey Information and Route Guidance and Navigation use cases.

The operations of the Travel Terminals class support all the interactions which actors of the class User may perform. These interactions can be performed through a range of hardware terminals ranging from a touchtone telephone to an interactive computer terminal. They might be performed in the home, at a street kiosk, or in-vehicle.

The operations of the Operating Interfaces class support numerous actors. Geographic Information Providers input data associated with transport routes. Service Enablers can notify effects on the transport network. Intermodal Providers respond to reservation requests. Yellow Pages Services can register and maintain their service data, and respond to service requests.

8.2 Traffic Management

This clause develops the class operations and interactions into a sequence diagram which describes the logical flows underlying the Traffic Management Use Case diagram.

8.2.1 Class Operations for Traffic Management

The operations of the abstract classes associated with the Traffic Management Use Case (Figure 16) are shown in Figure 26. These operations include:

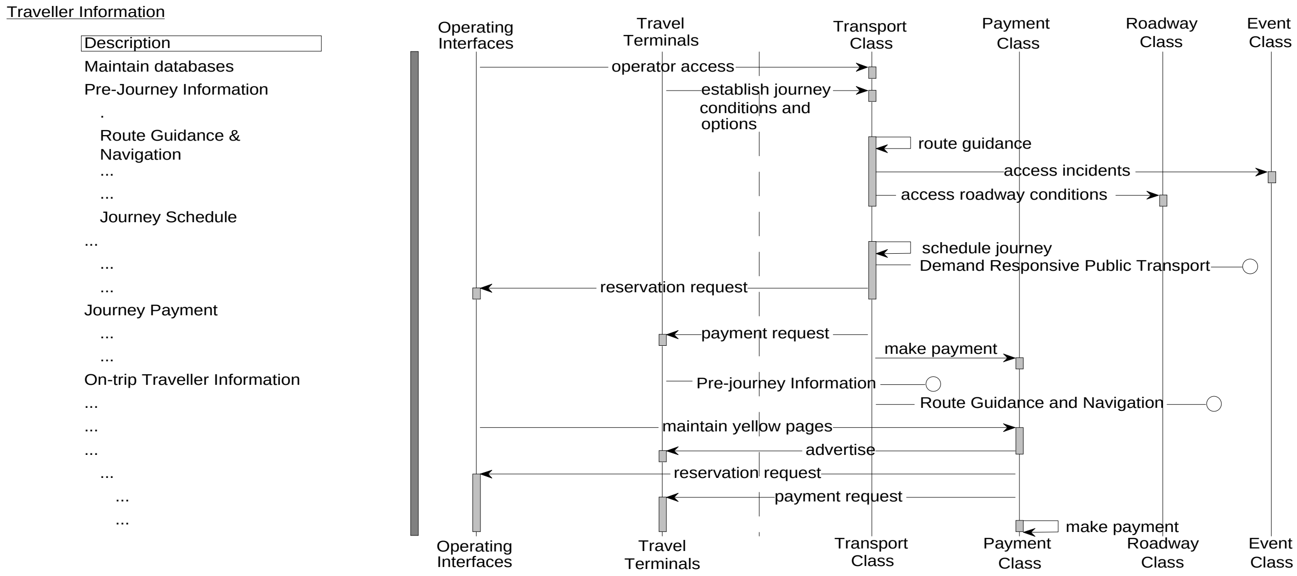

Figure 25 — Sequence diagram showing the main interactions and operations for the Traveller Information Use Case Diagram

Roadway Class

- actor access: This operation provides general support for all the actor types (e.g. Traffic Operator) that need to update and interrogate databases (information classes) through Operating Interface objects.

- compute control actions: This operation includes the decision making process which generates strategic and local control actions using the relevant databases (information classes).

- data fusion: This operation consists of analytical or deductive processes designed to detect and classify incidents using all the data (information classes) developed through other operations.

- evaluate: This operation consists of analytical processes which use the data derived from actor accesses and roadside peripherals to develop and store higher level performance measures.

- manage demand: This operation uses databases (information classes) which are generated by other operations and actor accesses in order to estimate current and future demand on the network and the environment, and to initiate responses.

- measure and local control: This operation is invoked by the range of roadside peripherals to update the databases (information classes) which contain all the low level performance data about the roadway network and environment; it returns local control data to the peripherals and initiates other operations.

- predict: This operation consists of analytical or deductive processes designed to use the databases (information classes) which record the historical and current data about the network and develop performance predictions.

- priority request: This operation processes requests from privileged vehicle interface objects and other classes and generates local or strategic control decisions.

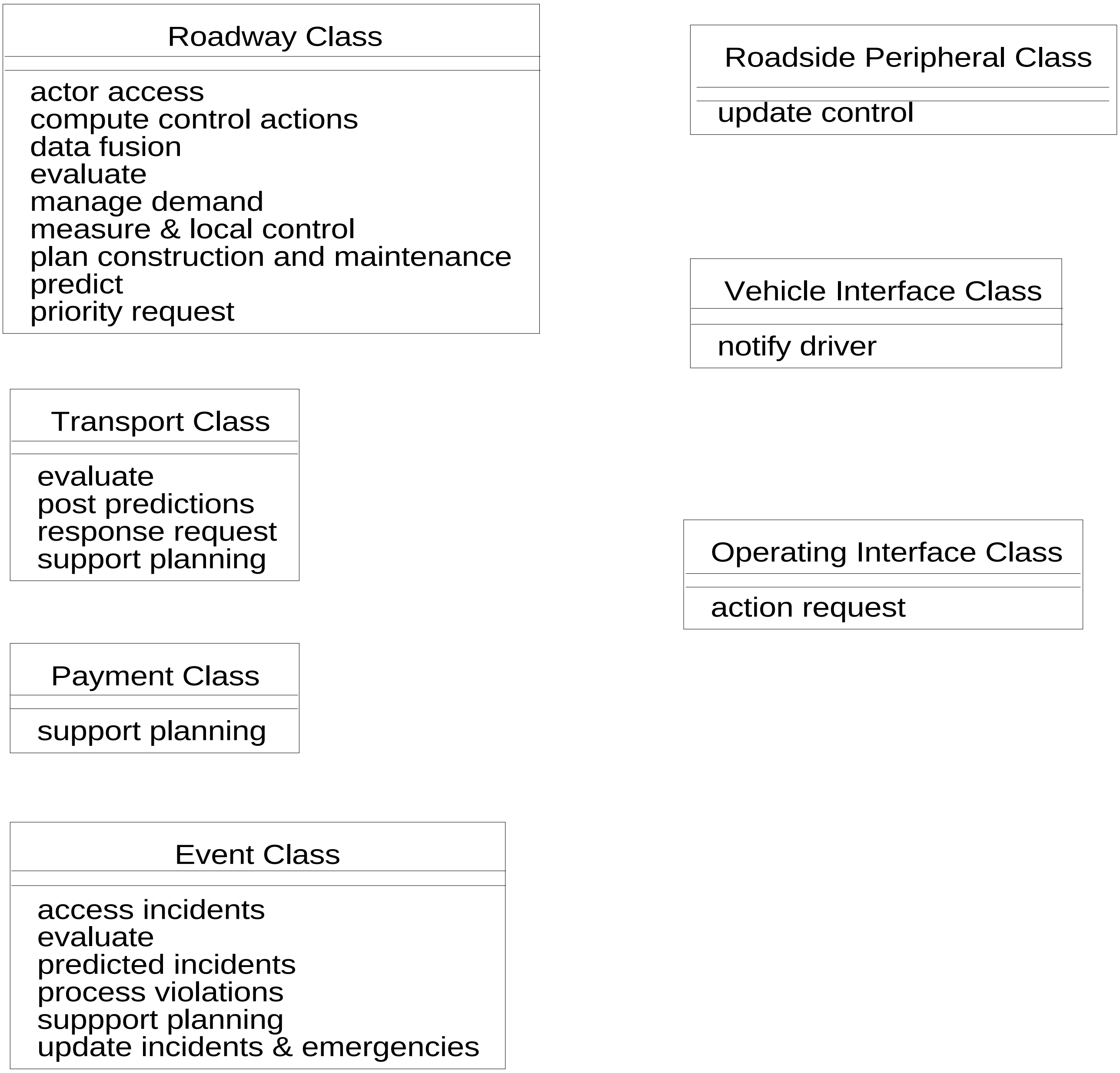

Figure 26 — Operations of the abstract classes relevant to the Traffic Management object interactions in Figure 27

Transport Class

- evaluate: This operation retrieves transport and route operational data for evaluation in a centralised process or subsequently accepts the results for storing in a database (information classes).
- post predictions: This operation updates the predicted performance for transport routes.
- response request: This operation responds to requests for adjustments to transport services.
- support planning: This operation allows the retrieval of data sets from databases (information classes) that describe transport operation and performance.

Event Class

- access incidents: This operation allows the retrieval of data sets from databases (information classes) that describe incidents and emergencies.
- evaluate: This operation retrieves transport and route operational data for evaluation in a centralised performance evaluation process or subsequently accepts the results for storing in a long term database (information classes).
- predicted incidents: This operation retrieves incidents which are predicted for a given notice period.
- process violations: This operation processes all types of violations committed by users of TICS or the roadway; it records data in information classes for subsequent action and may instigate notification in real time.
- support planning: This operation allows the retrieval of data sets from databases (information classes) that describe environmental incidents.
- update incidents and emergencies This operation creates new event objects and modifies them, according to parameters provided.

Payment Class

- support planning: This operation allows the retrieval of data sets from databases (information classes) concerning tariffs and their application.
- response request: This operation responds to requests for adjustments to tariffs.

Roadside Peripheral Class

- update control: This operation takes various control parameters as input and adjusts the operational control or characteristics of roadside hardware.

Operating Interface Class

- action request: This operation supports messages to actors to request various actions or notifications.

Vehicle Interface Class

- notify driver: This operation supports messages which are for Driver actors via hardware inside or outside the vehicle.

8.2.2 Traffic Management Sequence Diagram

The logic of the Traffic Management transactions is described in the sequence diagram of Figure 27

There are nested iterations, as shown in Figure 27 down its left-hand side. A major portion of these transactions is served by operations of the Roadway class, as shown in the approximate center of the sequence diagram.

The outer iteration would be very low in frequency compared to the inner iteration. The outer iteration contains actor involvement such as maintaining the geographic database (information classes) and the Transportation

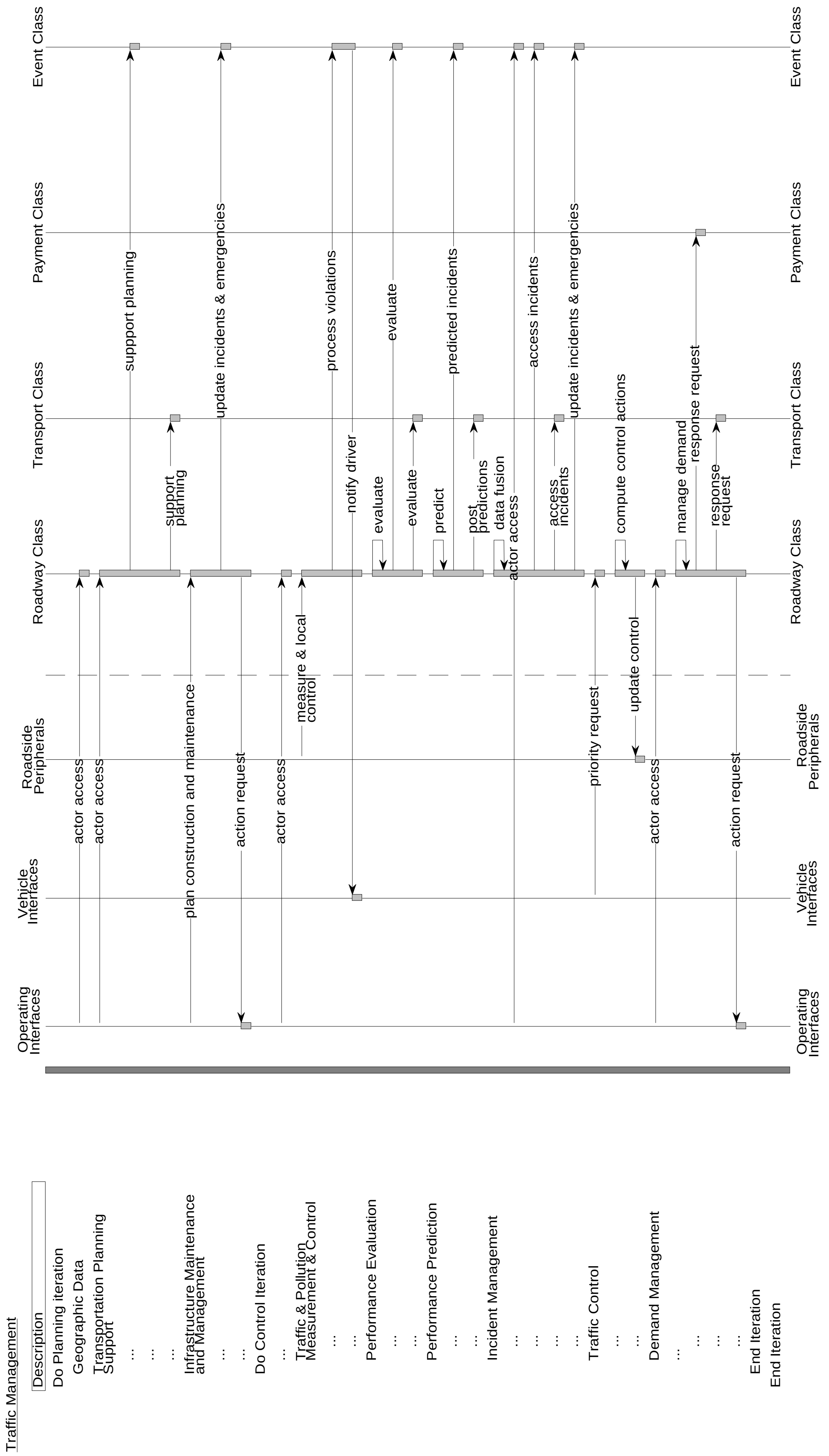

Figure 27 — Sequence diagram showing the main interactions and operations for the Traffic Management Use Case Diagram

Planning Support use case. The inner iteration contains the operational transactions corresponding to the other six use case.

Transportation Planning Support is centred in the Roadway class but requires interaction with all the other control and information classes in order to assemble relevant data for the purpose. These supporting operations are named “support planning”.

The operational loop consists of a number of different stages corresponding to the other six use cases. The highest frequency stage is that of Traffic and Pollution Measurement and Control. This is based in the Roadside Peripherals class that interfaces all the sign and sensor devices in the TICS system. This interface class assembles various input and output data and interacts with the Roadway class, providing real time data and receiving control data.

Particular events are processed in each cycle of Traffic and Pollution Measurement and Control. This pertains to the detection of all types of incident. In particular the violation of traffic regulations by individual vehicles is processed. The latter involves interaction between the Roadway Class, Event Class, Payment Class and Vehicle Interface class.

Higher level and lower frequency processing of the real time data occurs in the stages of Performance Evaluation and Performance Prediction. Evaluation requires interaction with the Transport and Event classes to obtain performance data. A performance database (information classes) is maintained in the Roadway class. This is followed by equivalent interactions and processing for the purpose of prediction.

The Incident Management stage is an extension of performance prediction to identify and combat particular incidents. Thus it relies on the established database (information classes) and further contributes to it. The Roadway class interacts with the Event class to derive control plans and set in motion other responses controlled through the Event class.

The Traffic Control stage serves both the normal and incident situation. Some control actions have already been put in place by the previous stages. It remains to do the final computation of control actions and respond to real time requests.

Demand Management uses the developed database (information classes) but goes beyond traffic control measures and requires control decisions. Interactions to support demand management occur with the Payment and Transport control classes

8.3 Vehicle

This clause develops the class operations and interactions into a sequence diagram which describes the logical flows underlying the Vehicle Use Case diagram.

8.3.1 Class Operations for Vehicle

The operations of the abstract classes associated with the Vehicle Use Case (Figure 17) are shown in Figure 28. These operations include:

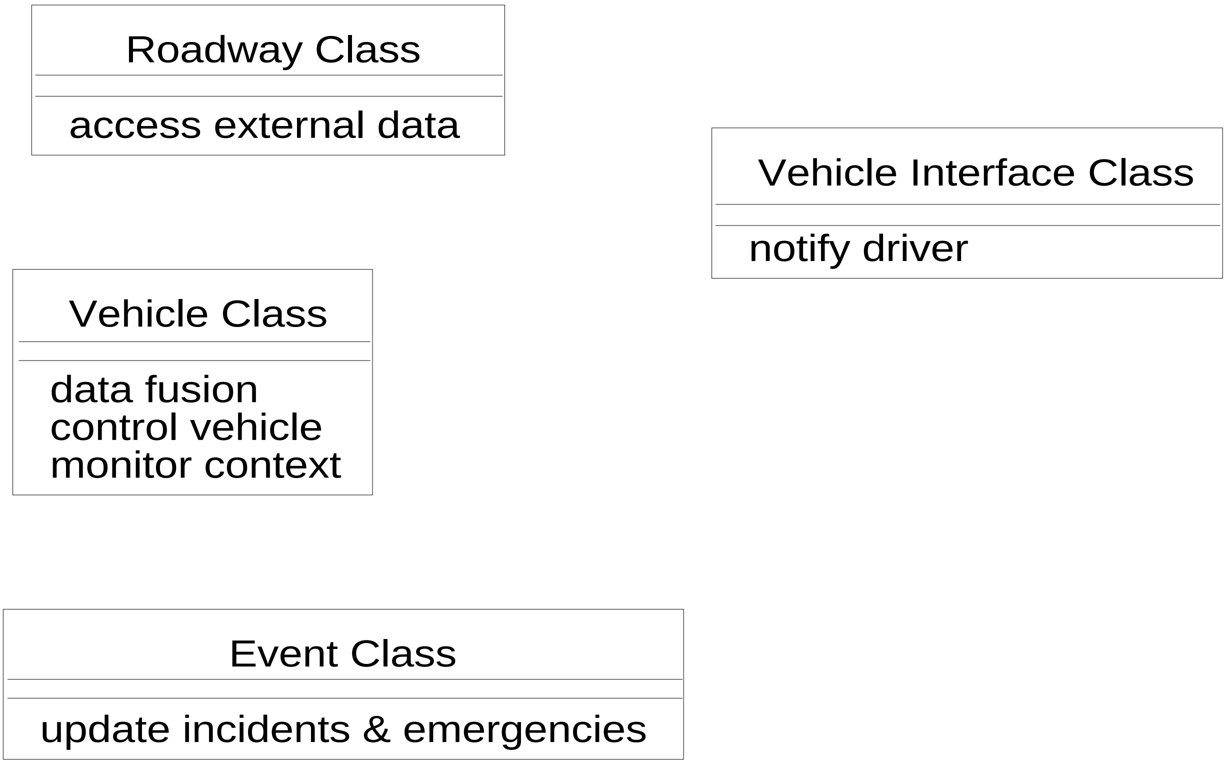

Figure 28 — Operations of the abstract classes relevant to the Vehicle object interactions in Figure 29

Roadway Class

- access external data: This operation provides real time roadway data relevant to a vehicle situation.

Vehicle Class

- control vehicle: This operation invokes the different levels of vehicle control from manual to advanced cruise control to automated highway.
- data fusion: This operation infers vehicle safety status in real time from data gathered about the in-vehicle situation and the roadway.
- monitor context: This operation monitors all aspects of the vehicle operation and driver performance in real time.

Event Class

- update incidents and emergencies: This operation creates the objects necessary to register and manage different types of incidents and emergencies.

Vehicle Interface Class

- notify driver: This operation supports messages for Driver actors communicated via hardware on-board vehicle or on the roadway.

8.3.2 Vehicle Sequence Diagram

The logic of the Vehicle transactions is described in the sequence diagram of Figure 29.

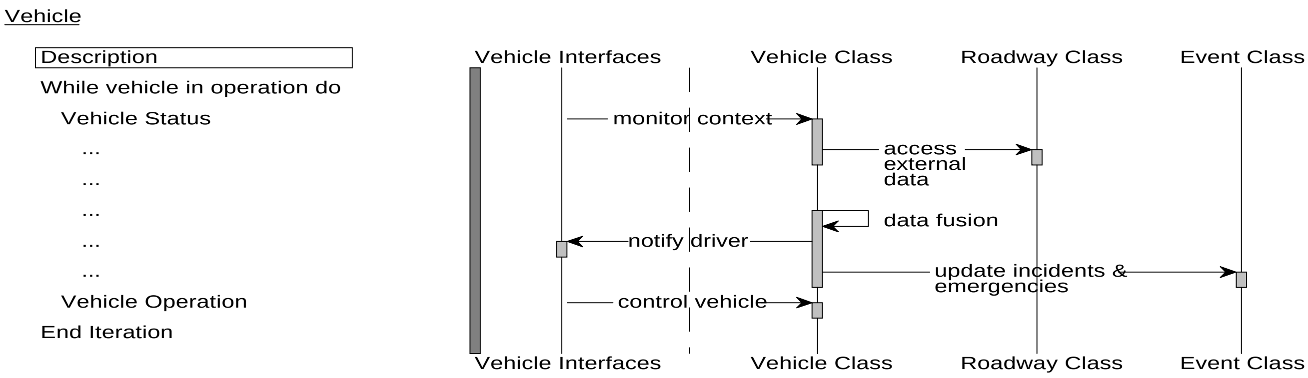

Figure 29 — Sequence diagram showing the main interactions and operations for the Vehicle Use Case Diagram

There is an iteration which lasts while the vehicle is in operation. The transactions of the Vehicle Status use case cover all the situations not covered by standard automatic control or automated highways. These transactions monitor the internal, inter-vehicle and roadway situation, and interact with the driver. They establish recognition of any incidents or emergencies.

The transactions are centred on the Vehicle Class but are dependent on the Roadway Class for access to data generated externally from the Vehicle. The Vehicle Class is dependent on the Events Class for data about relevant incidents and emergencies.

In the Vehicle Control use case the driver can initiate certain changes in the level of automatic control. The vehicle is then subject to the associated level of control. The relevant operations are in the Vehicle Class.

Operations of the Vehicle Interfaces class support the Driver interactions.

8.4 Commercial Vehicle

This clause develops the class operations and interactions into a sequence diagram which describes the logical flows underlying the Commercial Vehicle Use Case diagram.

8.4.1 Class Operations for Commercial Vehicle

The operations of the abstract classes associated with the Commercial Vehicle Use Case (Figure 18) are shown in Figure 30. These operations include:

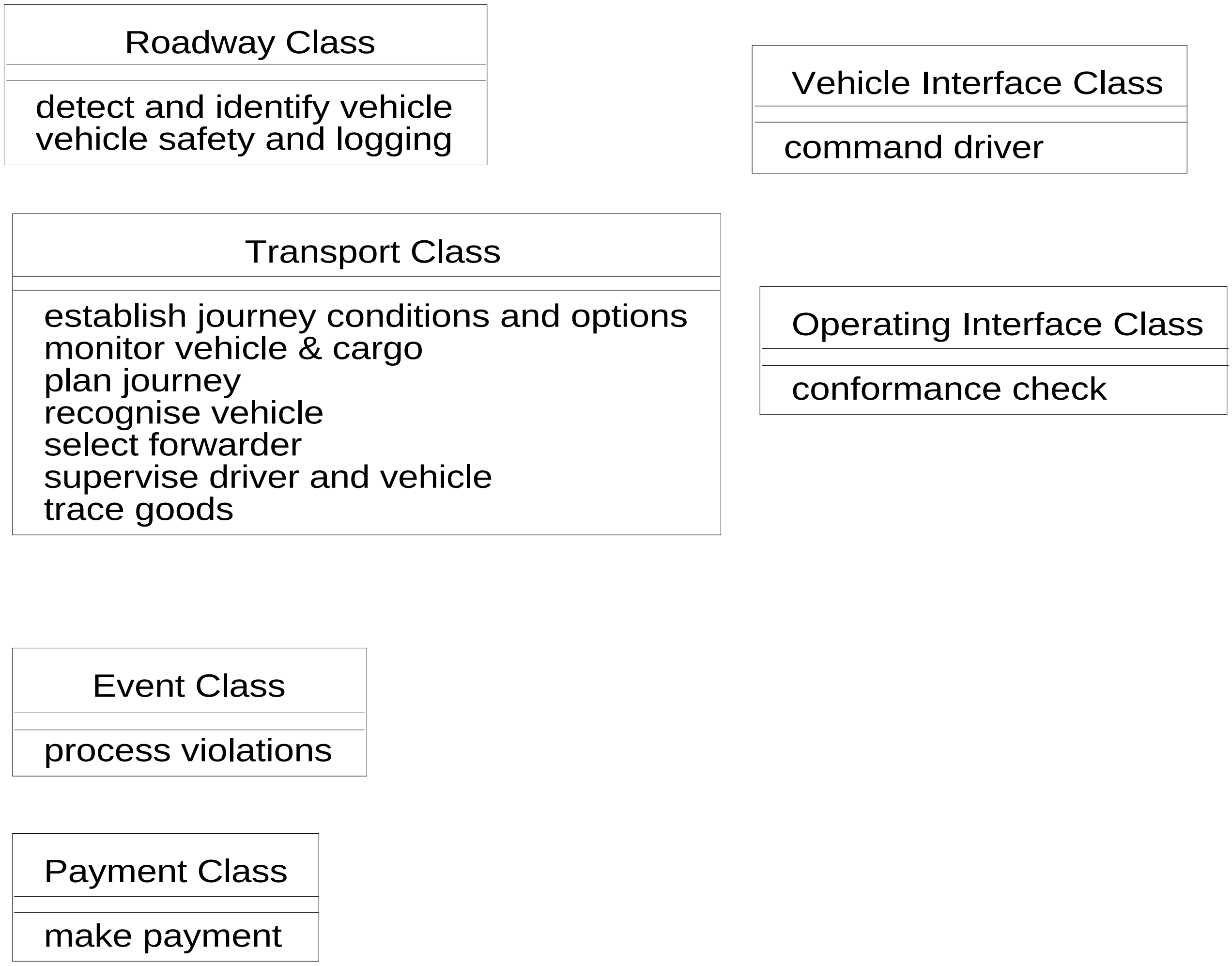

Figure 30 — Operations of the abstract classes relevant to the Commercial Vehicle object interactions in Figure 31

Roadway Class

- detect and identify vehicle: This operation takes input derived from roadside peripherals and does vehicle identification and classification.
- vehicle safety and logging: This operation carries out all roadside checking of a vehicle concerning safety, taxes and itinerary.

Transport Class

- establish journey conditions and options: This operation supports a Carrier Operator actor in initiating the planning of a tour or journey for a commercial vehicle.
- monitor vehicle and cargo: This operation monitors the state of a commercial vehicle and cargo in real time.
- plan journey: This operation uses data derived from a previous operation to register the commercial vehicle tour plan.

- recognise vehicle: This operation takes vehicle identification input and returns information about the vehicle, its cargo and itinerary, and its payment status.

- select forwarder: This operation supports a User actor in the selection of a Freight Forwarder actor using appropriate databases (information classes).

- supervise driver and vehicle: This operation allows the retrieval of the commercial vehicle and cargo data and the issuing of instructions to the driver by Carrier Operator actor.

- trace goods: This operation allows actors to check the progress of goods in shipment through a multi modal system.

Event Class

- process violations: (see 8.2.1)

Payment Class

- make payment: (see 8.1.1)

Vehicle Interface Class

- command driver: This operation supports messages which are for Driver actors via hardware inside or outside the vehicle.

Operating Interface Class

- conformance check: This operation supports the interaction with Conformance Agency actors so that the necessary credentials and tariff information can be provided about commercial vehicles.

8.4.2 Commercial Vehicle Sequence Diagram

The logic of the Commercial Vehicle transactions is described in the sequence diagram of Figure 31.

These transactions form a natural sequence. Order and Shipment supports the end user client and Forwarder. TICS supports a global database for the tracing of goods. Commercial Vehicle Tour Planning, Commercial Vehicle Administrative Processes comprise the tour preparation of each tour. Commercial Vehicle Road Operations corresponds to the execution of a tour.

Commercial Vehicle Tour Planning uses the use case Route Guidance and Navigation in the route planning process. Pre-payment of costs associated with the tour uses Journey Payment.

During the tour execution the Route Guidance and Navigation use case is invoked for ad hoc route guidance (via On-trip Traveller Information).

The transactions are mostly served by operations of the Transport Class. There is interaction with the Payment Class for the financial transactions of Commercial Vehicle Administration.

Operations of the Roadway Class check the Vehicle on tour. The Roadway Class is dependent on the Event Class for processing violations.

All the interface classes are needed to support a wide range of actor interactions. Operations of the Vehicle Interfaces class support the monitoring of vehicle and cargo, and communication with the Driver.

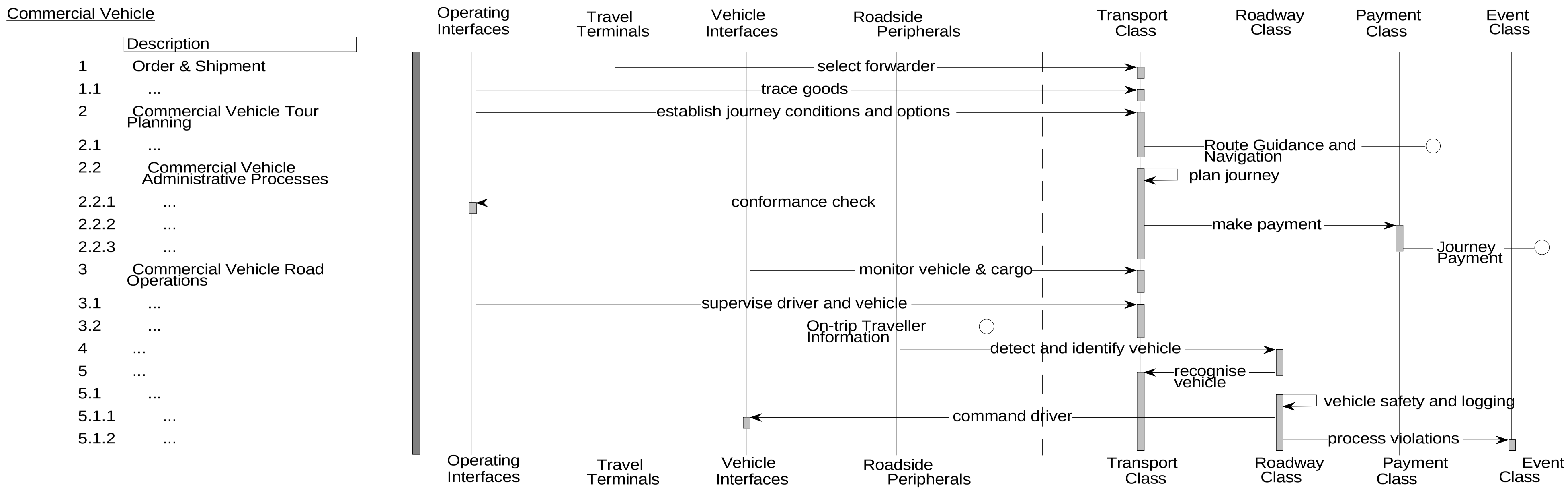

Figure 31 — Sequence diagram showing the main interactions and operations for the Commercial Vehicle Use Case Diagram

8.5 Public Transport

This clause develops the class operations and interactions into a sequence diagram which describes the logical flows underlying the Public Transport Use Case diagram.

8.5.1 Class Operations for Public Transport

The operations of the abstract classes associated with the Public Transport Use Case (Figure 19) are shown in Figure 32. These operations include:

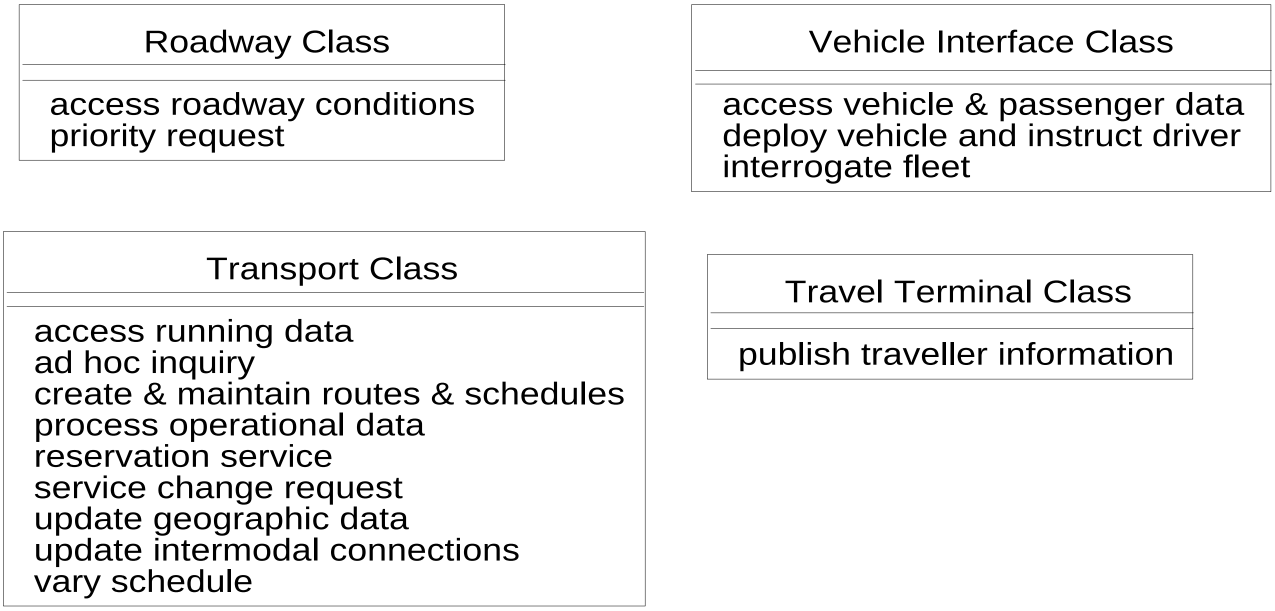

Figure 32 — Operations of the abstract classes relevant to the Public Transport object interactions in Figure 33

Roadway Class

- access roadway conditions: (see 8.1.1)
- priority request: (see 8.2.1).

Transport Class

- access running data: This operation retrieves public transport running data for Traveller purposes, on demand.
- ad hoc inquiry: This operation retrieves demand responsive public transport running data for Traveller purposes, on demand
- create and maintain routes and schedules: This operation covers the resourcing, routing and scheduling of time tabled services, and their maintenance.
- process operational data: This operation processes the public transport historical data, develops service changes and publishes them.
- reservation service: This operation processes an on demand public transport request.

- service change request: This operation processes requests for service changes from privileged actors.
- update geographic data: This operation maintains the geographic database (information classes) for public transport planning and scheduling.
- update intermodal connections: This operation maintains the intermodal database (information classes) for use in scheduling.
- vary schedule: This operation processes contingencies in public transport operation, develops service changes and makes the information available for inquiries.

Vehicle Interface Class

- access vehicle and passenger data: This operation provides operational data from public transport vehicles for use in the creation of centralised performance databases (information classes).
- Interrogate fleet: This operation provides operational data from on demand vehicles for use in scheduling.
- deploy vehicle and instruct driver: This operation supports vehicle dispatching.

Travel Terminal Class

- publish traveller information: This operation supports the publication of time tables.

8.5.2 Public Transport Sequence Diagram

The logic of the Public Transport transactions is described in the sequence diagram of Figure 33.

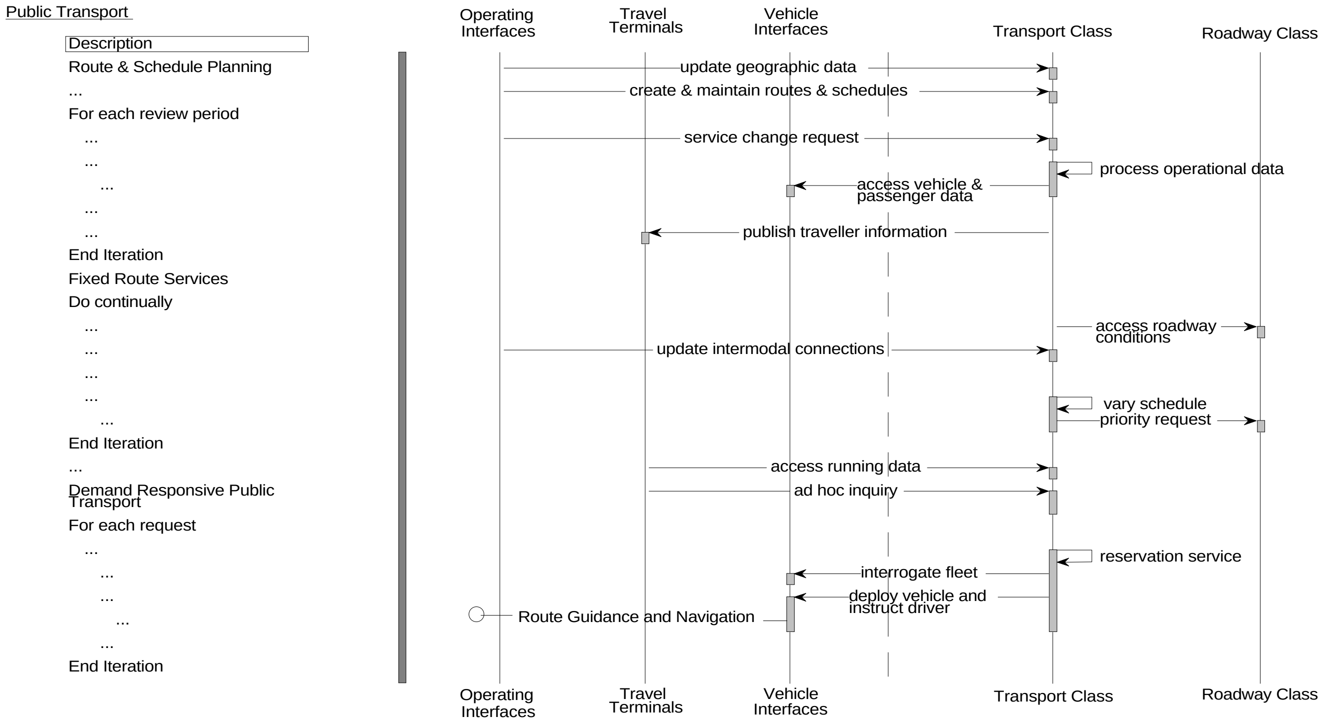

Figure 33 — Sequence diagram showing the main interactions and operations for the Public Transport Use Case Diagram

These transactions consist of independent iterations for the three use case. Route and Schedule Planning use case would be intensive for the establishment of routes and schedules but primarily consists of continuous improvement. The Fixed Route Public Transport use case iterates each time an external change or contingency arises. The Demand Responsive use case can be considered to iterate per demand.

The transactions are centred on operations of the Transport Class. There are dependencies on the Roadway Class for traffic priority and data on roadway conditions.

Operations of the Vehicle Interfaces class support access to data from the public transport vehicles and Driver communications. Operations of the Travel Terminals class provide traveller information and support Traveller interactions.

8.6 Emergency

This clause develops the class operations and interactions into a sequence diagram which describes the logical flows underlying the Emergency Use Case diagram.

8.6.1 Class Operations for Emergency

The operations of the abstract classes associated with the Emergency Use Case (Figure 20) are shown in Figure 34. These operations include:

Roadway Class

- priority request: (see 8.2.1)

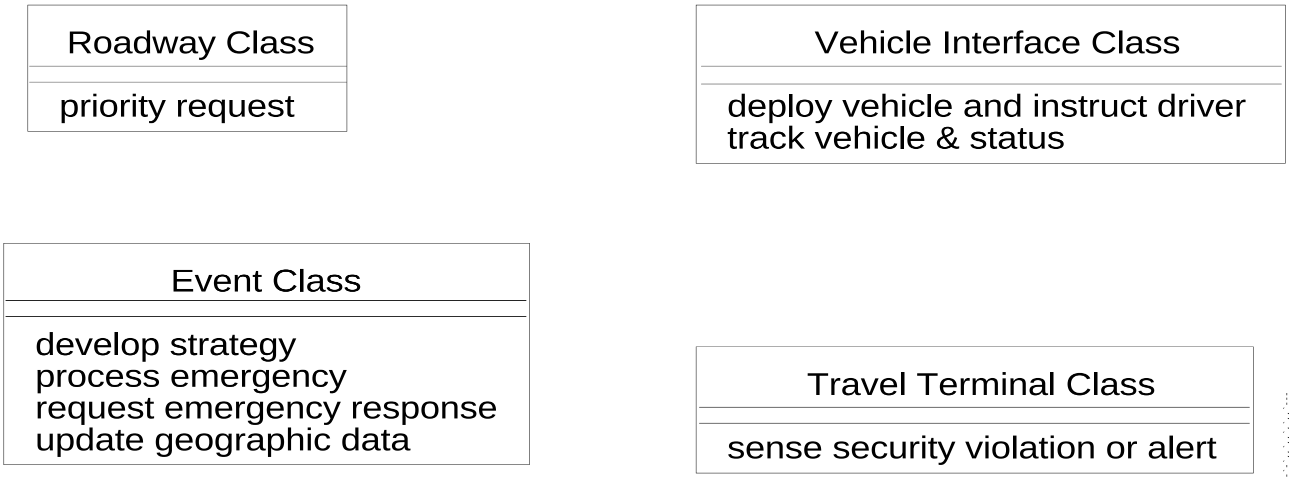

Figure 34 — Operations of the abstract classes relevant to the Emergency object interactions in Figure 35

Event Class

- develop strategy: This operation supports Emergency Service and Transport Planner actors to develop emergency response strategies, creating databases (information classes) which contain ready to use plans.

- process emergency: This operation supports Emergency Service actors and other packages to develop an emergency response, referring to the databases (information classes) which contain previously developed plans.

- request emergency response: This operation processes emergencies.

- update geographic data: This operation maintains the geographic database (information classes) for emergency planning, management and scheduling.

Travel Terminal Class

- sense security violation or alert: This operation processes the input from the various surveillance and notification devices.

Vehicle Interface Class

- deploy vehicle and instruct driver (see 8.5.1)

- track vehicle and status This operation monitors vehicle location and other input available from the vehicle or driver.

8.6.2 Emergency Sequence Diagram

The logic of the Emergency transactions is described in the sequence diagram of Figure 35.

Emergency Notification and Personal Security transactions apply to numerous situations where a possible emergency is detected or notified. Once the emergency event is established an iteration of the Emergency Resource Allocation occurs. Transactions which support the planning stage are also shown. The transactions of the Emergency Vehicle Management are conducted for each vehicle and emergency while vehicles are mobilised.

The transactions are centred on operations of the Event Class with dependency on the Transport Class for Route Guidance and Navigation and dependence on the Roadway Class for traffic priority operations.

Operations of the Travel Terminals class support security surveillance. Operations of the Vehicle Interfaces class support communication with the Driver.

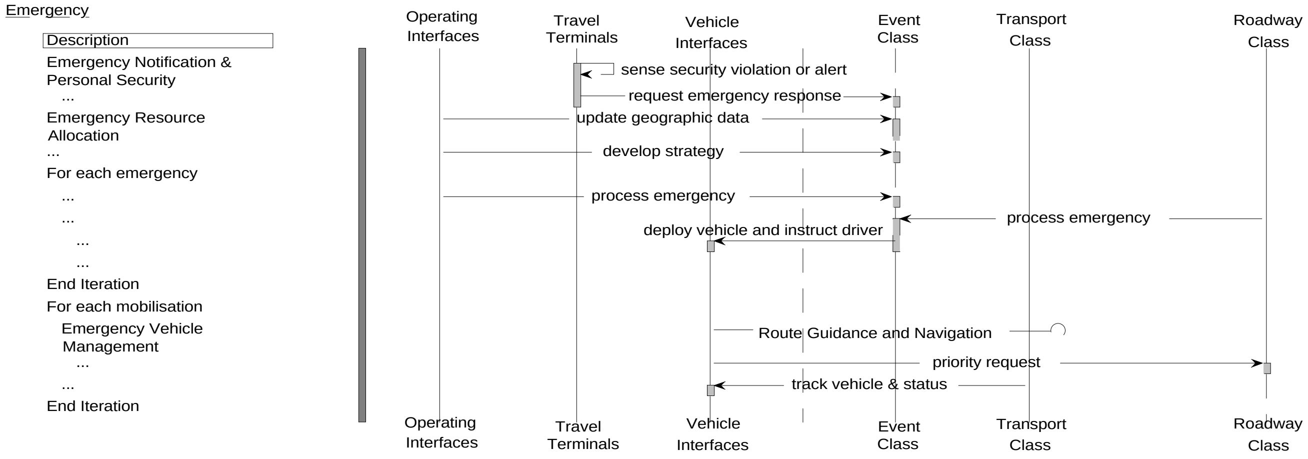

Figure 35 — Sequence diagram showing the main interactions and operations for the Emergency Use Case Diagram

8.7 Electronic Payment

This clause develops the class operations and interactions into a sequence diagram which describes the logical flows underlying the Electronic payment Use Case diagram.

8.7.1 Class Operations for Electronic Payment

The operations of the abstract classes associated with the Electronic Payment Use Case (Figure 21) are shown in Figure 36. These operations include:

Roadway Class

- accept user credit: This operation registers a User actor to use a roadway resource with credit; the appropriate records are established with Clearing Operator actors.
- detect and identify vehicle: (see 8.4.1)
- resource use statistics: This operation records probe statistics available from resource use such as with toll roads.

Event Class

- process violations: (see 8.2.1)

Payment Class

- compute charges: This operation computes the resource use charges.
- create billing record: This operation creates a record in an accounting database (information classes) for resource use; the record can be subsequently accessed for post-payment.
- declare tariff: This operation supports the establishment of tariff databases (information classes) in the system.

Travel Terminal Class

- debit: This operation executes debiting of the credit payment means provided by the User actor.

- pre-payment: This operation supports the establishment of credit by the User actor for services in advance and payment for services (e.g. fares) up front.

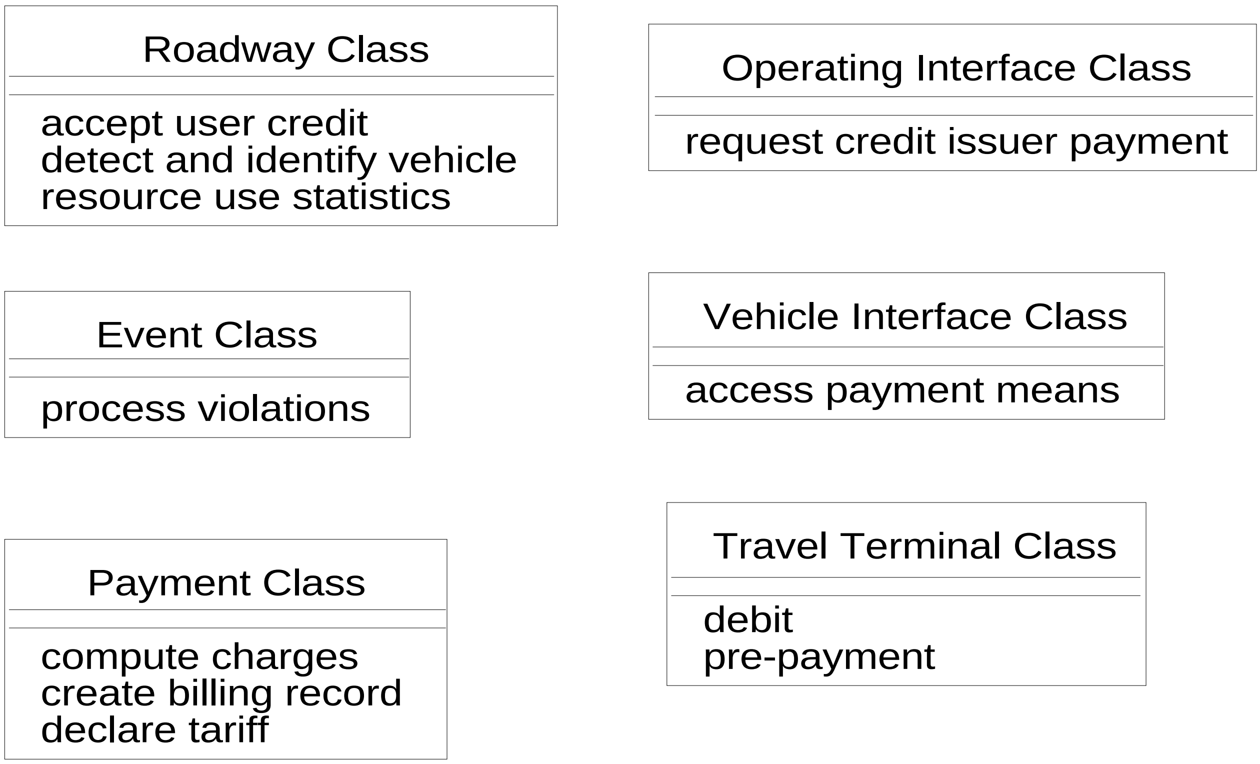

Figure 36 — Operations of the abstract classes relevant to the Payment object interactions in Figure 37

Operating Interface Class

- request credit issuer payment: This operation initiates external transactions by the Clearing Operator actor to transfer funds from the issuer for services provided.

Vehicle Interface Class

- access payment means: This operation provides credit identification to be used for payment for resources used by a vehicle.

8.7.2 Electronic Payment Sequence Diagram

The logic of the Electronic Payment transactions is described in the sequence diagram of Figure 37.

Payment Means covers any transaction that takes payment or establishes credit with a TICS service provider. Cash transactions may prime an electronic purse or debit from the purse. These transactions occur at will and any time a Traveller actor makes an up front payment.

Each resource use (or fare) met by credit payment involves transactions of two use case. Vehicle Charges (or Fare Collection) set up the accounting at the start. Payment Transaction is invoked at the end of service.

There is dependency on the Event Class for processing payment violations.

The Roadway Class is dependent on the Payment Class for all transactions which involve payment for use of resources.

Operations of the Vehicle Interfaces class provide the payment means for vehicles. Operations of the Travel Terminals class support other Traveller payment. Operations of the Operating Interfaces class provide an interface to the Financial actors.

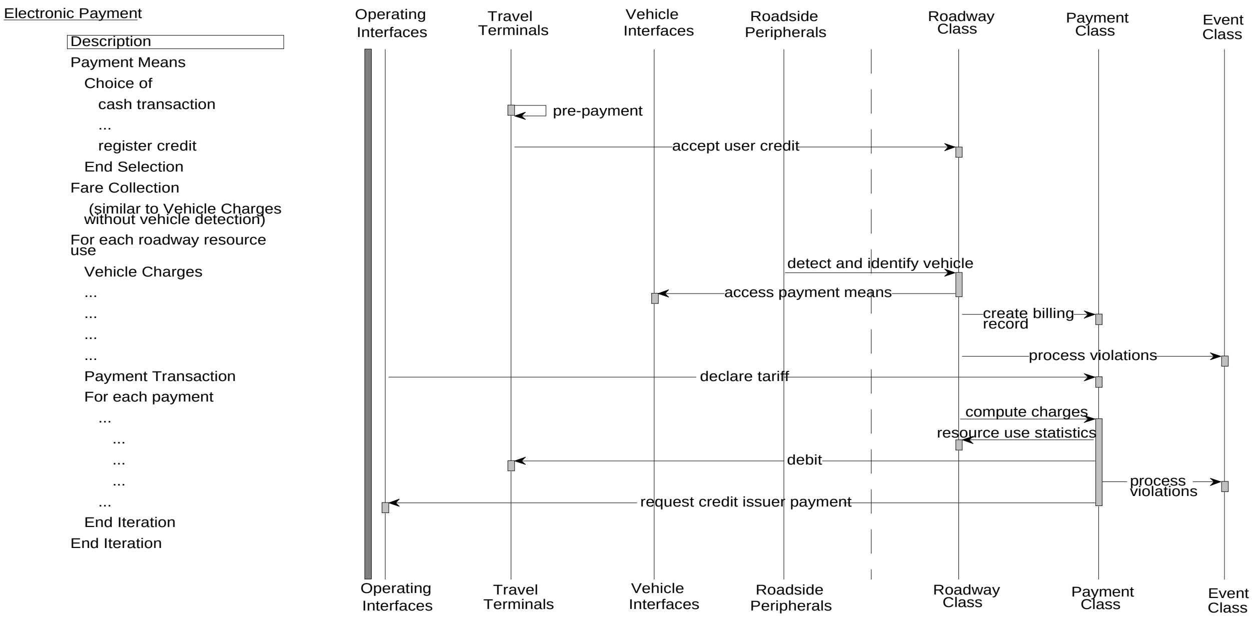

Figure 37 — Sequence diagram showing the main interactions and operations for the Electronic Payment Use Case Diagram

8.8 Safety

This section develops the class operations and interactions into a sequence diagram which describes the logical flows underlying the Safety Use Case diagram.

8.8.1 Class Operations for Safety

The operations of the abstract classes associated with the Safety Use Case (Figure 22) are shown in Figure 38. These operations include:

Roadway Class

- data fusion: This operation consists of analytical or deductive processes designed to detect and classify potential incidents and emergencies using all the data (information classes) developed through other operations.

Vehicle Class

- data fusion: This operation consists of analytical or deductive processes designed to detect and classify potential incidents and emergencies using all the data (information classes) developed through other operations.

Roadside Peripheral Class

- notify vulnerable: This operation supports messages which are for Traveller actors via hardware inside or outside the vehicle.

Vehicle Interface Class

notify driver: This operation supports messages which are for Driver actors via hardware inside or outside the vehicle.

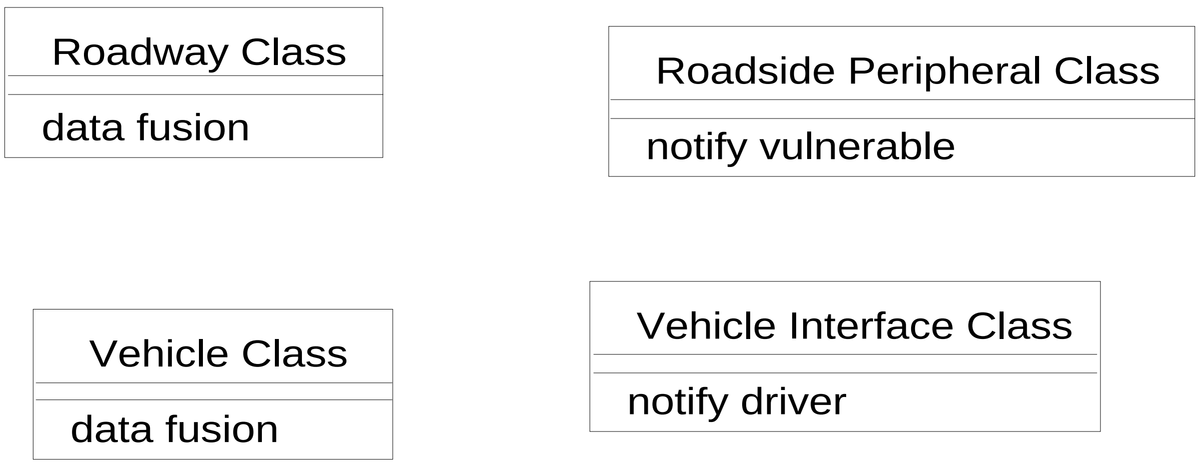

Figure 38 — Operations of the abstract classes relevant to the Safety object interactions in Figure 39

8.8.2 Safety Sequence Diagram

The logic of the Safety transactions is described in the sequence diagram of Figure 39.

These transactions are executed continuously for each local environment. They exploit detection done from the roadway and from on-board. They are centred on the Roadway Class and the Vehicle Class.

Operations of the Vehicles interfaces class alert drivers. Operations of the Roadway Peripherals class alert other Users.

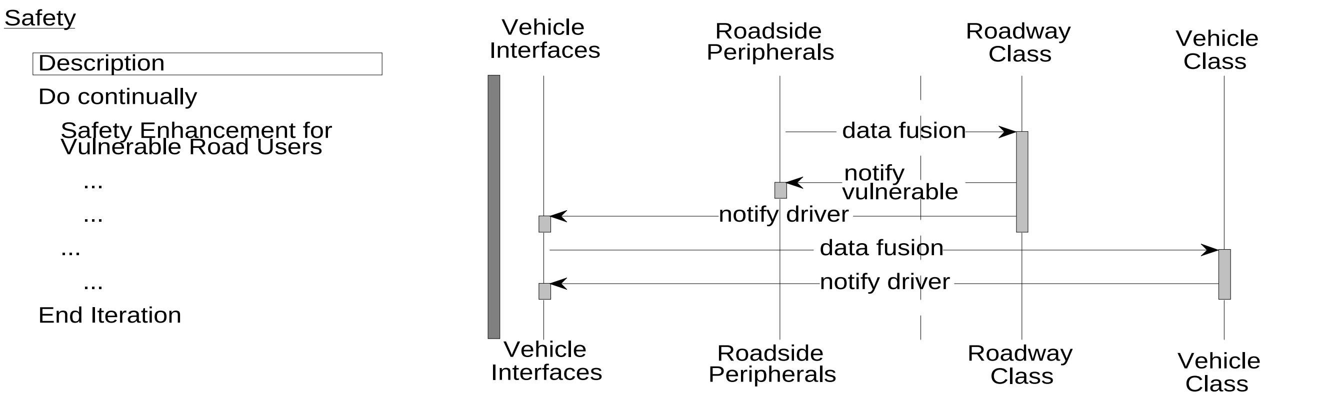

Figure 39 — Sequence diagram showing the main interactions and operations for the Safety Use Case Diagram

Annex A
(informative)

Core TICS Reference Architecture Development Approach

The Unified Modelling Language (UML) is a visual modelling language. A methodology is required to apply UML to developing an architecture. This clause offers some insight into such a methodology. New terms and graphics introduced in this clause are not part of the UML.

The development of an architecture for a complex system is never a simple sequential process. However there are clear relationships in any development methodology. Important relationships of a methodology can be identified by considering which UML elements and diagrams feed into others.

The methodology begins with a requirements gathering exercise for which the elements of use case diagrams are the main modelling aids. The use case diagrams are developed by considering the ‘why” and the ‘what’ of the rationale for the target system. Less formal documentation exercises may precede the generation of use case diagrams. TICS Fundamental Services are already documented in ISO/TR 14813 Part 1. These provide the basis for identifying actors and use case. The grouping of actors and use case, linked by relationships, allows the development of use case diagrams as indicated in Figure A.1.

The remaining part of the methodology is highly iterative. The textual documentation of a use case is formalised in a sequence diagram. Thus there is a primary input from use case to sequence diagram. However a sequence diagram cannot be built without classes for which the necessary operations have been defined. Thus there is also a primary input from class diagrams into sequence diagrams and it is necessary to define some classes before proceeding to any sequence diagram.

Another process, which occurs continually from architecture to design, is the replacement of an abstract set of elements with a more concrete set. This also exercises the iterative relationships shown in Figure A.1. Package diagrams are a useful modelling view for identifying modularity and concisely representing all the classes which are present on a class diagram. A package may be identified before its component classes.

The above comments have introduced the four views that are used in TICS architecture. The development of classes, which form the body of the architecture, is now discussed in more detail.

Invention is a key part of architecture development. In the methodology invention is centred on the definition of the classes and their operations. Reuse is an important concept in class definition. Thus classes are identified after consideration of all the use case which might apply. The relationships among use case are relevant and there is an iterative relationship in the development of class diagrams and use case diagrams.

The methodology for development of classes is based on a consideration of what is needed to provide the services of each use case. In object-oriented terms service implies invoking the operations of objects. Therefore classes are formulated under the three guidelines listed below, all the time connecting to reality.

- information
- control
- interface

By way of explanation the derivation of the example class diagram in Figure A.2 is given. The diagram contains five classes. The associations describe each Roadway Group object as an aggregation of a Roadway Network object, one or more Local Control Group objects and zero or more Parking objects. A Roadway Group object is associated with one or more Control Plan objects.

Information classes define objects which model information in the system that is held for a significant period of time, and which would typically survive one use case scenario. The operations of the information classes are primarily about creating, updating and accessing the data stored in their attributes.

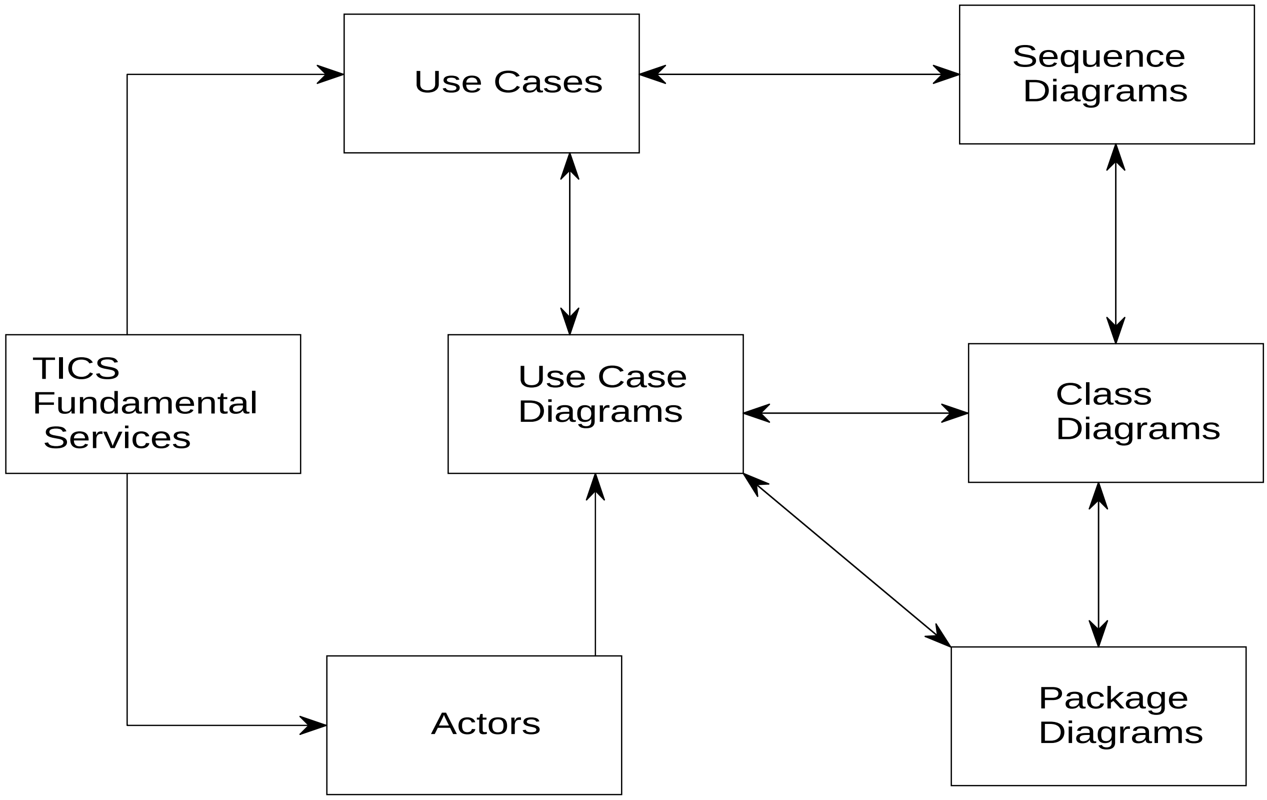

Figure A.1 — Development methodology relationships

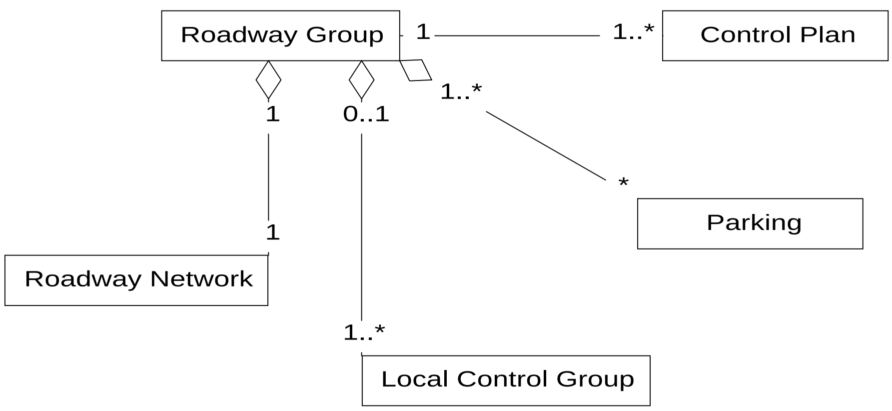

Figure A.2 — Class diagram with traffic management connotations

For example consider the use case named Traffic Control. Some of the information essential for this use case calls for a class named Control Plan. (We will not distinguish between the case where these attribute values are computed dynamically and the case where value sets are prestored.) The attributes of Control Plan embody the strategy to be applied, or parameters to be used in the computation of “traffic control”. Sometimes these objects are generated through another use case (Transportation Planning Support). The objects reside in the system for a long time, being subject to ongoing maintenance through the interactions of the actor Transport Planner.

For some actors an equivalent information class is required. These classes maintain information inside the TICS system about the actor objects, for example, the actor named Parking. The actor Parking is a class of external systems which operate autonomously, but which cooperate with TICS in use cases such as Traffic Control and Demand Management. There is a need for a TICS information class named Parking in order that the state of these actor objects can be maintained as continuously available information within the TICS system.

Traffic control requires a model of the traffic flow which is deeper than the individual elements of the roadway. So an information class called Roadway Network (which when analysed is an association between other information classes, such as Intersection and Link) is defined.

The class Roadway Group is an aggregate of the relevant component classes. However Roadway Group is not just an information class. It is primarily a control class (see below).

Control classes are defined to model functionality that is not naturally tied to any other class. For example, a control class might have an operation that consists of interacting with several different information objects, doing some computation, and then returning the resulting data to an actor.

Consider again the class Roadway Group of Figure A.2. This class is defined so that the traffic on the Roadway Network can be controlled by the system (e.g. Traffic Control, Incident Management and other use cases). There are numerous operations involved. An example of an interaction sequence based on the Roadway Group is:-

1. compute plan (Control Plan)

2. update control data (Local Control Group)

3. update control data (Parking)

Control classes have operations that are applied in one or more use cases. In the Reference Architecture, a control class will usually have an information role as well. Thus classes fall into a continuum between predominantly control and predominantly information.

The control class Roadway Group satisfies a good deal of its information functions through associations with other classes such as those depicted in the example of Figure A.2.

Control classes give rise to most of the dynamic characteristics of an architecture. The performance of an operation of a control class often results in messages being sent to other control objects, thereby causing a sequence of operations involving numerous control and information objects. These sequences are identified in the sequence diagrams.

An **interface class** is defined to model the process of capturing information from, and presenting information to, an actor which is by definition outside the system boundary. Thus the architecture boundary is formed by interface classes for all the different operator and external system roles, and for all the situations where users can interact with the TICS system.

As illustrated in Figure A.3 interface classes, control classes and information classes will all be involved in any actor transaction sequence (use case). The figure shows the different interaction paths amongst classes in the system. Actors indirectly invoke operations of the control and information classes by invoking an operation of an interface class.

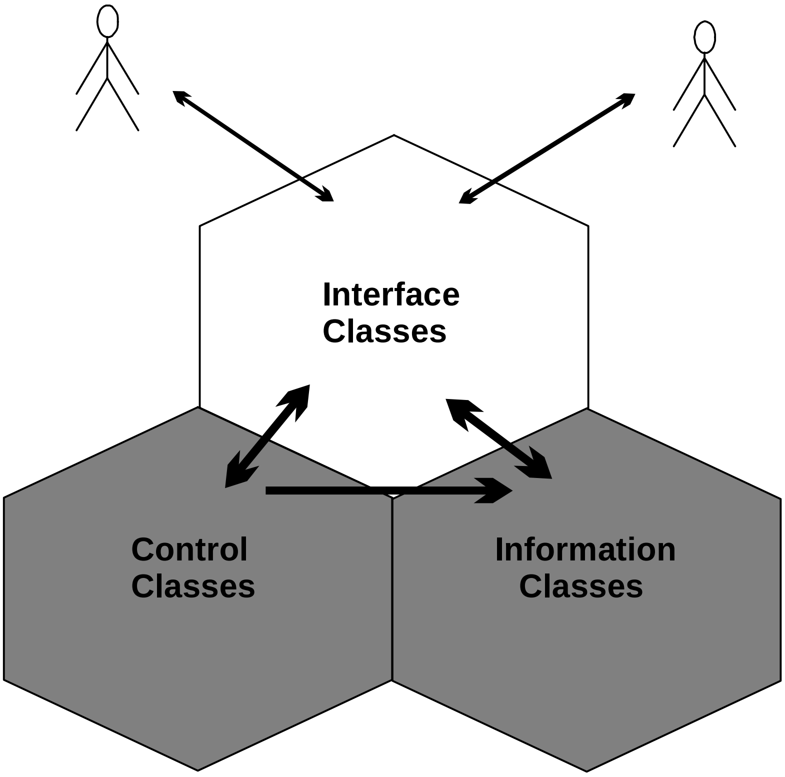

Figure A.3 — A schematic view of the cooperation between classes in a package

Bibliography

[1] Unified Modeling Language, UML Semantics, Version 1.1, 1 September 1997. Available on the Internet: <http://www.rational.com/uml>

NOTE At the time of the technical development of the TICS Reference Architecture, UML Version 1.1 was evolving. The software tool used in this effort provided one available presentation for UML diagrams. Since then UML Version 1.3 has been formalized and subsequently submitted to ISO under a Publicly Available Specification Procedure. UML Version 1.3 is being balloted as Draft International Standard ISO/IEC 19501

[2] The Unified Modeling Language User Guide, Booch G., Rumbaugh J., Jacobson I., Addison Wesley, 1999, ISBN 0201571684.

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