Transport Network Architecture

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Standard governance

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Preface

The Asset Standards Authority (ASA) is a key strategic branch of Transport for NSW (TfNSW). As the network design and standards authority for NSW Transport Assets, as specified in the ASA Charter, the ASA identifies, selects, develops, publishes, maintains and controls a suite of requirements documents on behalf of TfNSW, the asset owner.

The ASA deploys TfNSW requirements for asset and safety assurance by creating and managing TfNSW's governance models, documents and processes. To achieve this, the ASA focuses on four primary tasks:

- publishing and managing TfNSW's process and requirements documents including TfNSW plans, standards, manuals and guides
- deploying TfNSW's Authorised Engineering Organisation (AEO) framework
- continuously improving TfNSW's Asset Management Framework
- collaborating with the transport cluster and industry through open engagement

The AEO framework authorises engineering organisations to supply and provide asset-related products and services to TfNSW. It works to assure the safety, quality and fitness for purpose of those products and services over the asset's whole-of-life. AEOs are expected to demonstrate how they have applied the requirements of ASA documents, including TfNSW plans, standards and guides, when delivering assets and related services for TfNSW.

Compliance with ASA requirements by itself is not sufficient to ensure satisfactory outcomes for NSW Transport Assets. The ASA expects that professional judgement be used by competent personnel when using ASA requirements to produce those outcomes.

About this document

This document provides an overview of the proposed transport network architecture (TNA) and how it applies to TfNSW, describes the methodology adopted by the ASA in developing a transport network architecture framework, gives a description of the draft architecture and discusses the benefits to TfNSW stakeholders.

The ASA systems engineering group has developed this document to share its progress on developing a model-based systems engineering interpretation of the rail network. This document has been developed with consultation from the transport cluster and is developed with reference to the published transport network architecture framework.
This document provides a single reference and progress update for the development of the transport network architecture framework by ASA.

This document supersedes T MU AM 06003 TI *Development of a Transport Network Architecture Model*, version 1.0. This technical information is a second issue. Updates for version 2 are additional information to Appendix C, including step 15 to step 17. A new Appendix D 'Downloading the TNA model' is added.
Foreword

This document forms part of a suite of TfNSW systems engineering documents of which T MU AM 06006 ST Systems Engineering is the parent document. T MU AM 06001 GU AEO Guide to Systems Architectural Design also forms part of the systems engineering suite of documents that provides TfNSW and supplier organisations with guidance in the synthesis and development of system-level requirements, combining in an effective system architecture, upon which a robust and adaptive transport system design can be based.
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1. **Introduction**

The Asset Standards Authority (ASA) is developing a model for use by Transport for New South Wales (TfNSW) in order to provide a common transport network architecture (TNA) that will provide a robust framework for network asset planning and investment decisions.

Contemporary best practice for investment projects starts with the development of a well-defined set of business and system requirements. Experience has shown that without this, there is a significantly higher chance of rework, budget overruns, schedule overruns, commercial disputes, project delays and cancellations.

TfNSW is committed to implementing a model-based systems engineering (MBSE) approach to the development of investment projects in order to assist solution development and acquisition. This approach applies architecture frameworks to capture information from and about the system which can then be used to guide the development of a more precise set of requirements. Business and system requirements would consequently be improved as they are developed, based on a stronger understanding of the transport system (both now and at the anticipated time of introduction).

2. **Purpose**

This document describes the purpose, rationale, strategy and schedule of the ASA approach to developing the TNA.

It aims to provide a common understanding of goals, capabilities and concept activities to ensure effective engagement by key stakeholders. Furthermore, this document provides sufficient information to assist in understanding and navigating through the ASA TNA.

2.1. **Scope**

This document describes the TfNSW approach in developing and implementing an architecture model for the transport network of NSW.

The document focuses on the development and implementation of the TNA content for the transport passenger system. The initial intention was to expand the scope of the TNA to include other rail transport modes such as rapid transit metro and light rail. The TNA currently contains information from the heavy rail mode of transport and some preliminary work in light rail, but nevertheless there are generic elements which can be used in future for other modes of transport, such as buses and ferries. Therefore as the TNA matures, it will then be able to support inter-modal transport of commuters.
2.2. Application

This document is intended for use by TfNSW (including agencies) and any AEOs that are responsible for developing business and system requirements specifications. This document can also be used by the wider transport industry as a resource to understand the steps taken in developing the TNA, and its relevance to architecture models.

This document can be referred to during AEO scoping meetings to elaborate on systems architecture requirements or architecture work involved in the feasibility, concept and design stages of the life cycle.

This document has been written so that the user is capable of applying system architecture design principles defined in T MU AM 06001 GU AEO Guide to Systems Architectural Design. Appendix C of this document shows a sample walkthrough of the TNA into multiple perspectives, views and viewpoints.

3. Reference documents

The following documents are cited in the text. For dated references, only the cited edition applies. For undated references, the latest edition of the referenced document applies.

**Australian standards**

AS ISO 10007 Quality management systems – Guidelines for configuration management


**Transport for NSW standards**

T MU AM 06001 GU AEO Guide to Systems Architectural Design

T MU AM 06004 ST Requirements Schema

T MU AM 06006 ST Systems Engineering

**Other reference documents**

Department of Defense Architecture Framework (DoDAF) 2010

Director General of Transport for NSW June 2012, Sydney's Rail Future: Modernising Sydney's Trains, State of New South Wales


Ministry of Defence architecture framework (MODAF) 2012
4. Terms and definitions

The following terms and definitions apply in this document:

**AEO** Authorised Engineering Organisation

**ARM** automated requirements assessment

**ASA** Asset Standards Authority

**architecting** process of conceiving, defining, expressing, documenting, communicating, certifying proper implementation of, maintaining and improving an architecture throughout a system’s life cycle (AS/NZS ISO/IE/IEEE 42010)

**(architectural) perspective** In this context, referred to an architectural perspective. Sharing of architectural models also facilitates an ‘aspect oriented’ style of architectural description; that is, a grouping of related and overlapping architectural views.

**(architectural) view** work product expressing the architecture of a system from the perspective of specific system concerns

**(architectural) viewpoint** work product establishing the conventions for the construction, interpretation and use of architecture views to frame specific system concerns

**BRS** business requirements specification

**DoDAF** Department of Defense Architecture Framework

**DBSE** document-based system engineering

‘**has part**’ in this context, 'has part' is a common stereotype used for the 'aggregation' relationship in the TRAK metamodel. This stereotype identifies a fraction or piece of something (TRAK 00002)

**ISO** International Organization for Standardization

**LTTMP** Long Term Transport Master Plan (NSW)

**LUL** London Underground Limited

**MBSE** model-based systems engineering

**metamodel** a model intended to give an all-inclusive picture of a process or system containing a collection of concepts (element types, attributes and their relationship) within a certain
domain. The TRAK metamodel defines the element types, their attributes and the relationships between the types

**MODAF** Ministry of Defence architecture framework

**OMG** Object Management Group

**RSSB** Rail Safety and Standards Board

**SME** subject matter expert

**SOA** service-oriented architectures

**SRS** system requirements specification

**SysML** systems modelling language

**TfNSW** Transport for NSW

**TNA** transport network architecture

**TRAK** abbreviation of The Railway Architecture Framework, a general enterprise architecture framework that sets the rules to develop systems architecture models across the aerospace, defence and transport industries, and is based on MODAF (TRAK00002 2010-2017, TRAK Enterprise Architecture Framework Metamodel)

**UML** unified modelling language

**UPDM** unified profile for DoDAF and MODAF
5. **Background**

With the introduction of the Asset Standards Authority (ASA), and the development of the Authorised Engineering Organisation (AEO) framework, it was highly likely that each AEO would interpret standards and approach engineering disciplines differently unless guidance is made available for them to follow.

To help ensure that AEOs adopt a uniform approach to engaging with Transport for NSW (TfNSW) for various transport projects, a model-based approach to engineering for the NSW railways was proposed. The principles around this strategy are that there should be an upper level of commonalities such as:

- a language that ensures consistency between and across engineering disciplines from a standards and engineering perspective
- a type approval process for new and novel systems, equipment and technologies
- an understanding of the elements and operational entities of the NSW transport network
- a consistent and collaborative approach to the documentation and presentation of standards
- an ability to clearly link standards to functions of the NSW transport network
- an open standards approach to the development of engineering to prevent dependence on any proprietary system of software or hardware
- promotion of new international standards and technologies

Furthermore, the approach has to ensure that the resulting transport network architecture (TNA) will support the evolution of the system as new technologies are introduced.

This document provides an introduction to the TNA, outlines the processes that the ASA is using to develop and model the architecture framework, supplies a background on architecture frameworks and explains why these are being applied to support TfNSW.

6. **Review of architecture frameworks**

The use of an architecture framework is common practice to create, interpret, analyse and describe a particular domain of application or stakeholder community.

AS/NZS ISO/IEC/IEEE 42010:2013 *Systems and software engineering – Architecture description* defines an architecture framework as:

> "conventions, principles and practices for the description of architectures established within a specific domain of application and / or community of stakeholders".

Building upon the requirements for specifying architecture descriptions, this standard also specifies requirements that a framework should identify. This includes a set of stakeholders,
architecture concerns and a set of viewpoints framing those concerns. Architecture frameworks identify the types of data that can be captured when describing a system. These data can be represented through architecture views and elements such as:

- enterprise – an organisation having ‘bottom line’ goals, often a collection of divisions and organisations
- enterprise goal – an objective or target for an enterprise
- capability – the ability to carry out a particular kind of action or the extent of someone’s or something’s ability
- concept activity – a high-level logical activity or process that is independent of how the activity is carried out
- function – an activity which is specified in the context of the resource (human or machine) that performs it
- metric – a measure
- organisation – an organised body of people associated for a particular purpose
- standard or document – a formal document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for purpose

These elements are generally presented in various diagrams in different architecture views. The architecture view is a work product expressing the architecture of a system from the perspective of specific system concerns. Viewpoints are grouped within views that collect aspects within a common perspective. Therefore, a perspective is the highest-level representation of information which is broken down into a set of views, each containing a set of viewpoints.

The TNA can be developed through the use of both structural and behavioural modelling approaches. Structural modelling describes the network functions and their relationships, including:

- functional hierarchy – which describes the functions, not the assets; for example, asset = escalator, function = permit vertical movement
- physical architecture – which describes how functions are apportioned or deployed to physical systems and assets
- geographic architecture – which describes how functions and assets are deployed geographically on the transport network
Behavioural modelling uses diagrams to describe how the network functions behave, for example:

- use case diagrams that describe how functions are grouped within a system and how external 'actors' interact with these functions; actors can be humans or external systems
- sequence diagrams that describe how various functions and actors interact with each other in processes over time
- activity diagrams show a sequential flow of inputs, outputs and control, specify sequence and conditions for coordinating other behaviours

In the defence industry, the two most widely-used frameworks are the Department of Defense Architecture Framework (DoDAF) in the USA and the Ministry of Defence Architecture Framework (MODAF) in the UK.

In developing the TNA, the TRAK Enterprise Architecture Framework Metamodel, published by the UK Department of Transport, has been used as a guide. However, it is anticipated that future work will utilise the wider perspectives provided by the more capable framework, UPDM (Unified Profile for MODAF and DoDAF).

Section 6.1 describes why TRAK was selected as the framework for the TNA.

6.1. The UK railway architecture framework

The ASA based its initial TNA model on the TRAK metamodel. TRAK (The Railway Architecture framework) is a general enterprise architecture framework that sets the rules to develop systems architecture models across the aerospace, defence and transport industries and is based on MODAF. TRAK was developed by the UK Rail Safety and Standards Board (RSSB) and has been used by London Underground Limited (LUL) and UK Network Rail since 2011.

TRAK conforms to the standard for architecture description AS/NZS ISO/IEC/IEEE 42010 and is tied to the systems engineering life cycle defined in ISO/IEC/IEEE 15288. The definition of TRAK is concerned with the 'what', not the 'how', so at any time there may be implementation of a TRAK conceptual and system design. A summary of the TRAK metamodel content can be found in Appendix A. TRAK defines five perspectives, which are explained in Section 6.1.1 to Section 6.1.5.

6.1.1. Enterprise perspective

The enterprise perspective covers the enduring capabilities that are needed to fulfil the goals of the larger enterprise. This perspective defines the overall enterprise and its scope, goals, capabilities, and metrics; and identifies the organisations that manage and realise them. These are high-level needs to which everything else contributes, and form part of the long-term strategic objectives. The enterprise view provides a mechanism to link into higher-level goals such as those described in the NSW Long Term Transport Master Plan.
6.1.2. Concept perspective

The concept perspective in the TRAK architecture covers the logical view of what is needed to support the capabilities in the enterprise perspective. It provides the logical connections between the solutions and business needs.

TRAK refers to the activities within this perspective as 'concept activities' and defines them as:

"a high level logical process which is independent of how the activity is carried out".

6.1.3. Procurement perspective

The procurement perspective provides information about projects that are being undertaken. This perspective includes views that provide the project structure (such as milestones), timeliness and associated responsibilities. The procurement perspective has not been utilised in the TNA since the TNA is not project-specific. However, this perspective may be utilised by a project team if they wish to extend onto the TNA.

6.1.4. Solution perspective

The solution perspective of the TRAK metamodel provides views of the operational solutions to the concept activities. There could be more than one solution that meets the needs expressed in the concept perspective. This level of the model represents a hierarchical structure of 'functions' which realise 'concept activities'. TRAK defines a function as:

"an activity which is specified in context of the resource (human or machine) that performs it".

6.1.5. Management perspective

The management perspective provides administrative content as well as other content that doesn't necessarily fall within the other perspectives mentioned above. This perspective includes data (glossary) and the ability to specify requirements and standards that constrain the transport system.

6.2. Unified profile for DoDAF and MODAF (UPDM)

UPDM is a standardised way of expressing DoDAF and MODAF artefacts using the Object Management Group’s (OMG) Systems Modelling Language (SysML), as well as OMG's XMI which is a standard for interchange. Standardisation for model data and Unified Modelling Language (UML) or SysML mapping means that both tool vendors and industry can provide models in a single format. It is therefore worth studying how the UPDM instructions can be employed to implement an architecture framework based on the TRAK metamodel.

Similar to TRAK, UPDM is partitioned into a number of viewpoint blocks. However, there are more viewpoints provided, and variants exist to UPDM to support different communities, which
changes some of the terminology slightly to suit the target audience. The terminology used in UPDM is based on MODAF aligned to TfNSW terminology. UPDM viewpoints are defined in Section 6.2.1 to Section 6.2.7.

### 6.2.1. All viewpoint

This set of views provides information pertaining to the complete model. These views include a summary of the model with intent and reference materials such as the data dictionary.

### 6.2.2. Strategic viewpoint

The strategic viewpoint contains views that outline the desired capabilities of the system and how these capabilities apply to the overall needs of the enterprise at large. This is similar to the TRAK enterprise viewpoint which captures a breakdown of the enterprise goals to capabilities and how these will evolve over time. Summaries are also included to understand how these capabilities are realised.

### 6.2.3. Operational viewpoint

The operational viewpoint examines how the system operates generically with minimal reference to implementation or technology (beyond generic terms dictated by the system structure). These views outline the states and modes of the system along with the behaviour of the system within these modes. With the behaviour are the exchanges required between system elements. These views also include organisational descriptions that outline roles and responsibilities of people within the system.

This viewpoint is similar to the TRAK concept perspective.

### 6.2.4. Systems viewpoint

The systems viewpoint is used to describe a system or systems that realise the information in the operational viewpoint. In these views, specific systems and technologies are identified and described in further detail. These are mapped against the operational viewpoint information and connected to the higher level needs of the system.

### 6.2.5. Services viewpoint

The services viewpoint enables the support of service-based depictions such as service-oriented architectures (SOA). TRAK has no equivalent to the services viewpoint, but discussions with practitioners have shown that this viewpoint is rarely applied using current system description approaches.
6.2.6. **Acquisition viewpoint**

The acquisition viewpoint provides the views needed to depict acquisitions and changes to the system over time. While the application of these views is based largely on changes made to the system as equipment is upgraded or retired, these can also be used to depict how maintenance approaches apply to the various systems.

6.2.7. **Technical viewpoint**

One way that UPDM differs from TRAK is that it includes technical viewpoints that aim to identify and relate the application of standards. This viewpoint identifies the standards of interest and can forecast future changes in the standards to be applied.

7. **Design of the ASA TNA structure**

It was recognised that the size and complexity of TfNSW could yield a large and extensive model that could become untenable unless carefully structured. It is important to structure the TNA to enable users to be able to efficiently access information pertinent to them.

Development of the structure has been driven by a variety of factors. These factors include the TNA metamodel, the modelling philosophy to be applied, support for both TRAK and UPDM, and the ability to support various forms of application. These factors are described in Section 7.1.

7.1. **TNA schema**

A transport network architecture model offers a reference framework to define ‘solution agnostic’ enterprise goals, network capability, concept activities and functions. While developing the TNA metamodel, the following tasks were noted:

- creation of topic-based network standards
- performing network functional analyses
- carrying out network performance analyses
- identifying network asset configuration information
- supporting network design and develop network asset planning practices
- assist in procuring new or altered assets
- establish robust set of business requirements
- synthesising functional and performance system requirements

The TNA can support the understanding of interrelationships and interfaces between functions, various system elements and components. It will assist specifiers of requirements for new or
altered assets to understand and specify comprehensive business level, functional level and system level requirement specifications for proposed works.

The architecture provides the capability to map standards from a document view to functions from a solution view, into one model. This will assist AEOs in applying relevant standards.

Figure 1 shows how the TNA feeds into the network requirements (next tranche of work), and also how these both contribute to topic-based standards.

### 7.2. Underlying modelling philosophy

A modelling philosophy has been adopted to improve the usability of the architecture model and increase efficiency in disseminating information. This philosophy is outlined in Section 7.2.1 to Section 7.2.3.

#### 7.2.1. Separation of data from views

This makes the distinction between the data within the framework and the views into the data that are available. The data area is dedicated to the objects identified as a part of the framework and the relationships between these objects. The data area is subdivided to co-locate like data, so that users are guided towards the data in order to reduce the likelihood that similar or repeated entries are created. Views are then made separately from these data. An advantage in this separation is that views need not display all of the information and so can be filtered to ensure that the appropriate message is conveyed. This separation has made it easier to find the right information in the framework and has resulted in re-usability of data when multiple users are involved.
7.2.2. Customised and constrained views

When constructing views, there are several aspects considered: the message, audience, presentation and the existence of other associated views that need to be linked to the view under construction. There are times where all of the available information is dumped into a diagram which makes it difficult to clearly gather and understand the desired information. By focusing on access to the needed information, and the intended audience, non-pertinent information can be filtered out to help quickly convey the intent. This aspect also constrains the amount of information being presented.

Moreover, large complex diagrams, while complete, can be difficult to follow. Therefore a particular message may be partitioned into a family of views that will guide the user to the relevant information for various activities. How a user navigates between these views and to other associated diagrams then has to be considered, which is heavily dependent on the type of user. While some users are comfortable using standardised languages such as SysML to receive information, others prefer different representation. Some diagrams may be depicted slightly differently to cater to various audiences even though the content is consistent. Therefore it is important to ensure that the presentation of views and perspectives are 'fit-for-purpose' to facilitate decision-making.

7.2.3. Framework navigation through views

The derivation of views needs to be combined with the architecting of the navigation to allow the users to efficiently find the necessary information. The 'previous', 'allocation' and 'element hyperlinks' can then be constructed to support the users in navigating through difference views. Framework navigation has also required the development of a small number of 'All views' diagrams to act as an entry point into the framework before entering a particular view.

7.3. Overview of TNA structure

Many of the architecture frameworks that the ASA wishes to apply have a common structure and only differ in the defined terms. The TNA has therefore been structured based on the architecture frameworks that could be applied. The TNA structure has divided the architecture into manageable sections that provide a coherent and structured model. The structure was developed from the enterprise, concept, management, and solution viewpoints represented in the TRAK metamodel and the boundaries from UML-based design.

Figure 2 shows the high level structure of the TNA, where an 'enterprise' view is supported by a 'concept' view, that itself is realised by a 'solution' view. The engineering disciplines that support the transport network (heavy rail, light rail, bus network, ferry network, and so on) all interconnect and contribute to developing the physical, system or resource items that form the solutions represented in the 'solution' view. Alongside this structure is the management
information that applies across all layers, capturing requirements and standards as they are specified.

![Architecture model structure]

**Figure 2 - Architecture model structure**

### 7.4. Generic depiction of the system's needs

The TNA has to indicate ‘what’ the system needs to achieve. The derivation of these needs is the aggregate of the needs from the system’s various stakeholders, found in transport strategy and planning documents. These needs are subsequently examined to identify the system capabilities that have to be exhibited in order to realise these needs. Metrics can also articulate the measures by which the system can or will be tested, and how such measures relate to the capabilities to be achieved.

It is important to recognise that increasing demands placed on the system and realising a set of needs over time may require the evolution and increased levels of some capabilities to meet those demands. As many systems require substantial lead times to acquire and implement, the information contained in the TNA supports the acquisition and implementation of a system or asset to meet future needs as they arise.

### 7.5. Generic depiction of transport architecture

The TNA is to be used to depict the various modes of transport generically. This depiction helps understand the elements and how these effects extend to other parts of the system.

The generic depiction of a transport mode identifies the terms for generalised system elements, the behaviour exhibited by those elements and the exchanges made. Exchanges are represented in the form of item exchanges which consist of energy (such as power), data or...
physical (such as nodes) items exchanged. These are gathered into various contexts to help understand the system interactions and justify their inclusion.

The generic depiction is intended to be mapped onto the system needs region of the TNA so as to identify the capabilities delivered by a transport mode and by extension, the needs to be met. This relationship therefore relates the evolving level of capability to the types of system that have to deliver them.

The TNA has been developed to be implementation and technology-independent as much as the mode of transport allows. It is recognised that some aspects of the system are going to change over time as new ways of undertaking operations are adopted, and so the TNA has tried to reflect this as cleanly as possible. For example, the transition from the existing signalling system to in-cab signalling will move functionality into the trains and will redefine the signalling system into something vastly different from the current incarnation.

7.6. Depiction of actual system to realise the generic

During the system definition phase of the life cycle (conducted during design), there are usually multiple parties involved in defining a system that realise the business needs and requirements. The TNA facilitates design of an actual system through the scoping of a generic system with its associated functions. For example, there are different types of rolling stock vehicles found operating in the heavy rail network such as Waratah, Millennium, Oscar, Tangara, C-Set, S-set and K-set. Each of these realises the generic system description of rolling stock. Some of the realisations may be common to multiple types, while others will be unique to their source type. The TNA can be used to articulate how several types of realisations allow for re-use of subsystems, plus identifying common equipment already installed.

7.7. Transport network evolution

The NSW transport network is complex and constantly evolving, incorporating new technologies, additional services, and resolving issues as they arise. One of the issues when acquiring a new asset or service into the transport network is the time taken to plan, design and implement the asset or service, while reducing risks to a minimum. For this reason, it is important to be able to capture how and when the transport system will evolve. Such information has significant benefits, including:

- identifying how the various versions of the asset or service will interface at particular times during the evolution
- relating the asset or service to the long-term goals to ensure that they are met
- discerning the analyses needed to ensure that the transport systems meet predefined criteria or objectives
8. Implementation of the TNA

Substantial work has been done to develop the TNA and improve its overall usability. The TNA has been built using a system architecture tool with an initial development that has focused on heavy rail. The implementation has been undertaken with forethought about the ability to capture multi-modal information. Since 2013, the overall implementation of the TNA has contained the following three phases of work:

- **Phase 1 – Identifying the scope of work (2013 to 2014)**
  
  Phase 1 of the project commenced in September 2013 and involved identifying the scope of work and architecture schema, which initially focused on heavy rail based on TRAK. A preliminary framework was developed, presented and workshopped with internal and external stakeholders.

- **Phase 2 – First draft of the TNA (2014 to 2015)**
  
  Phase 2 of the project was completed in 2015 with the development of the first draft of the TNA. A consultation process was developed where the TNA was presented at a number of workshops with relevant subject matter experts (SMEs). The success of the first draft was established through the achievement of the following aspects:
  
  - suitability for use by service providers and technical managers from government and private industry
  - functions within specialist areas were appropriately captured
  - language and terminology consistent with all discipline-specific TfNSW standards
  - easy navigability through an HTML export

  During the development phase of the first draft, the ASA was going through a change by not only focusing on heavy rail, but all other modes of transport such as light rail, metro, buses, ferries and so forth.

  Within this phase, enhancement tools were also developed to improve the quality of the data and eliminate unnecessary elements while reducing development effort. Some of these tools aided in the standardisation of diagrams through a diagram formatting tool, validation of content, anomaly detection, orphan control and distribution of model data.

- **Phase 3 – Publication of the TNA on the ASA website (2016 to 2017)**
  
  The final version of the TNA will capture the enterprise, concept and solution views of the framework. While focusing on the implementation of the TNA and expanding the scope to all modes of transport in 2016, additional views were established that are not provided by the standard TRAK metamodel. These additional views include document, requirements, metric and all views.
8.1. The TNA structure

The TNA is partitioned into four areas:

- model views, that contain the diagrams that allow users to see the data and see it from various perspectives
- model elements, that contain the model’s underlying database
- problems, that have been identified while reviewing the TNA
- stereotypes area, that contains the stereotypes that have been custom-created to support the TRAK metamodel and other administrative customisations

Stereotypes are applied to classify the elements in each diagram. This is a concept applied to many modern system architecture tools that helps the user identify what an element in the model is. Attributes can be identified for a stereotype that is then inherited by the objects that have that stereotype applied. For example, a ‘requirement’ stereotype applied to an element then identifies that object as a requirement, which subsequently inherits the requirements fields as described in T MU AM 06004 ST Requirements Schema.

This results in an area dedicated to the views that enable users to see the information in the model database. Separation of the views from the database enables finding elements that already exist, ensuring easier re-use, and provides useful summaries of the various types of elements. The various views also allow ease of interpreting and maintaining the TNA. The model browser of the database is depicted in Figure 3.

![Figure 3 – Model browser TNA structure](image-url)
The '0 Stereotypes' region in Figure 3 provides general structures used to customise the tool set and provide structures that have been developed to customise the architecture model.

The '3 Problems' region is used to create placeholders in various diagrams that identify issues already detected and which await resolution. This has been proven as an effective way to track unresolved issues.

One of the reasons why the TNA structure is partitioned into these four areas is because display of all the elements and relationships in a single diagram is not practical. As a result, the four areas were created to present subsets of the information in standardised diagrams. The development of what is presented in a diagram began with identifying the information to be depicted. In some cases, there was information represented in UPDM which TRAK did not provide. Appendix B of this document provides a sample mapping between TRAK and UPDM.

8.2. Diagram identifier scheme

The '1 Model Views' partition in Figure 3 contains a large number of diagrams with a variety of content and for different purposes. This causes problems in being able to identify which diagram should be consulted when looking for particular types of information. Architecture frameworks partially solve this problem through the development and use of a diagram identifier scheme that categorises all the diagrams from multiple disciplines and modes of transport.

The ASA has therefore developed a TNA diagram identifier scheme based on the conventions used on their publications. This scheme (shown in Figure 4) begins with identifying the architecture framework standard set (shown as 'AF set' in Figure 4) from which the diagram is based. Currently both TRAK and UPDM are supported. However, the ASA has identified diagrams that it wishes to develop which do not conform to either TRAK or UPDM.
Figure 4 – TNA diagram identifier scheme
This identifier scheme (Figure 4) allows all three architecture framework sets to be utilised concurrently and therefore enables the diagram developers to select the ‘AF set’ that best suits their purpose and audience.

In the identifier scheme, the 'AF set' is followed by the 'AF view' and 'AF perspective'. Since the TNA is intended to be multi-modal, the next element in the identifier scheme is the mode of transport being depicted. This is then followed by the discipline being captured in the diagram. Finally, some text is included to help the user understand the content of the diagram.

Accordingly, a diagram representing concept activities in the concept view that applies to more than one mode of transport and a fleet of some sort of transport stock will have the diagram name; for example: [TRAK_CV-05-MU-RS] accelerate, maintain speed, brake and stop, as shown in Figure 5.

![Figure 5 – Sample diagram ID](image)

The purpose of the TNA diagram identifier scheme is to quickly convey the intended content of the diagram, along with the mode of transport and discipline applied. This multi-dimensional naming convention will benefit the user in helping reduce the time required to find the diagram.

### 8.3. Description of enhancements for increased usability

Enhancement tools were developed by the ASA to improve the quality of the data and eliminate unnecessary elements while reducing development effort. Section 8.3.1 to Section 8.3.2 documents the rationale behind developing each type of enhancement tool.

#### 8.3.1. Standardisation of diagrams and structure

The TNA has a specific structure both for the underlying data and the arrangement of the diagrams that are created. However, novice users may not understand the structure (and its underlying reasons) and formatting diagrams can be a time-consuming task that adds little intellectual content. Therefore a series of automated routines have been added to reduce overall effort and ensure that the resulting data model meets ASA standards.

- **Integrate new content into model:** Ensuring that new data are properly integrated into the TNA can be time-consuming and mistakes are easily made, so a function that helps insert new content has been developed. This function takes the content external directory to the TNA and moves it into the appropriate areas of the TNA, which ensures retention of the TNA's integrity and decreases the time spent on unnecessary labour.
Diagram formatter: The amount of time spent performing simple formatting tasks such as laying out the boxes for consistent size and locations has already been substantial. Therefore a routine has been developed that will reduce this effort by automatically performing some of this activity. The formatter is applied to a diagram which examines the elements and colours based on the TRAK standard. The formatter then ensures that the elements are being displayed appropriately for the diagram type (for example, boxes rather than images) and turns on word wrapping. The formatter also resizes the boxes so that they are consistent. This routine then examines the type of diagram and if there is a predefined format, the routine then lays out the diagram. This is being populated as the standard layouts for the identified diagram types.

8.3.2. Validation of the model and anomaly detection

These tools aim to give indications of the 'quality' of the data. To reduce perceptions of the 'garbage-in, garbage-out' problem, a set of tools has been created to assess and make assertions about the quality of the data and to locate potential issues within the framework.

Requirement text validation: Automated requirements assessment (ARM) has been a topic since the early 1990s when NASA developed the ARM tool that utilised a word identification routine to detect problems in written requirements. Having such an assessment capability is seen as valuable and therefore a variant of ARM has been integrated into the TNA. This enhancement has been added as validation routines to the validation engine so that the errors appear in the error report and erroneous requirements are highlighted in the various diagrams and navigation panes. Additionally, once a user has indicated that a particular item is not an error, the report is not re-generated.

Orphan control: It is anticipated that groups within TfNSW will develop content that will be integrated into the TNA once it is sufficiently mature, using the integration routine described above. During these model mergers, tool exchanges and related activities in evolving the content, it is recognised that it is easy for objects to be created but which no longer exist in diagrams (referred to as ‘orphans’). Orphans could be as follows:

- extraneous elements from drafts
- deleted from diagrams, but not the model itself
- legacy data or elements accidentally removed that should appear in some diagrams

Therefore a routine was created that would find orphan elements and move them out of the TNA and into a location for review. The user can then either delete the elements, or find the appropriate diagrams that they should appear within and return them back into the TNA.

Content validation: The content validation tool is designed to test the content for common issues and resolve them as best as possible. The need for the tool initially came from
identifying that some information (particularly relationships) can be replicated as it is constructed in different diagrams. This can cause issues as changes to one occurrence are not applied to the other occurrences in other diagrams in the TNA database. Therefore a tool was developed to identify and merge these replicated elements so that all the diagrams display the same data and not replicated versions. This routine will be further enhanced to rectify issues as specified by ASA best practice in the future.

The automatic resolution may not always select the representation that a user might have manually performed. For example, a link may be replicated as two different types (such as an association and a dependency) and the routine will remove one where the user may prefer the other. This can be easily rectified by the user when they discover the change by using the refactor function to convert to the preferred type. Because this tool has merged all representations in all of the diagrams, the representation will change in all diagrams resulting in a consistent representation across the entire TNA.

- **Model validation checking:** The TNA enables automatic checking of the content for validity. Some model validation is already undertaken by the requirement checking tool that highlights erroneous requirements. This functionality has been widened to highlight issues that can be automatically detected for quick resolution. For example, the system architecture tool set we have used is less constrained on the information contained in objects than the TfNSW requirements schema currently being used. Checks need to be made of the attributes in requirements to ensure that they do not conflict with this schema and cause problems when exchanging data. This routine examines the types and structures found in the TNA and applies validation rules in a manner similar to those applied to validate the requirements.

### 8.3.3. Distribution of data and information

Data distribution is an important activity within TfNSW as concepts and decisions made by some organisations naturally impact others both up and down the system life cycle. The TNA provides a means for better communication between these organisations through the development of a common, correct and consistent view of the system for all parties to reference, and to act as a conduit for data to flow between the organisations (transport cluster and AEOs). It is assumed that each organisation will have its own tools to support their processes, and to support this vision, import/export tools are needed to help with data distribution.

There are also a variety of tools, models and simulations that are used to provide feedback and guidance. There are currently many instances within TfNSW where information is manually moved between these tools. Integration of these tools into a systems engineering tool environment ensures that data are consistent between the various tools and reduces this transfer effort. This section describes some of the tools developed to facilitate these exchanges.
• **Excel import**: The ASA initially used Excel as its preferred format for capturing requirements, and this is expected to remain common practice with other TfNSW stakeholders for some time to come. Therefore it is necessary to be able to import files that are developed, using Excel, into the TNA so that the data can be subsequently linked into the remaining data structures.

• **Customised requirements management tool interface (DOORS)**: DOORS is currently the specified requirements management tool in several TfNSW divisions. While DOORS is a good choice to integrate into the tool environment, it is not the preferred method in sharing TNA requirements. However a decision was made to develop a customised interface between the two tools, as the interface is intended to act as more than a mere data transfer, instead enabling a degree of processing between the TNA and DOORS. The existing commercial interfaces are capable of transferring data, but customisation would be needed to process these data so that they are appropriately linked and utilised in the TNA.

9. **The transport network architecture (TNA)**

This section provides a description of each perspective in the TNA.

The ASA is developing enterprise, concept and management perspectives of the TNA. These perspectives interconnect to allow multiple users to navigate through the model and easily understand the interfaces and interactions of the complex transport network. The perspectives are defined as follows:

• **enterprise perspective**, expresses the high level and enterprise needs and capabilities of the system.

• **concept perspective**, contains logical processes that describe what is needed to support the capabilities in the enterprise perspective, independent of how the activities are performed. The concept perspective also contains a solution view which relates to the engineering disciplines and provides the solutions that could meet the needs expressed in the concept view.

• **management perspective**, contains auxiliary information (such as standards and competencies) linked to the other views such as document and requirement views.
Figure 6 shows the relationship between the three perspectives.

Management Perspective

Enterprise Perspective

Concept Perspective

Supports
Supports
Supports
Supports

Realises
Realises
Realises
Realises

Function
Function
Function
Function

Document view

Requirement view

9.1. TNA enterprise perspective

The long-term strategic objectives of TfNSW provide the business needs for the enterprise perspective. The enterprise perspective (also referred to as the strategic perspective) of the TNA is coloured in green in the ‘model content overview’ diagram, as shown in Figure 7.

TfNSW enterprise goals are derived from transport and government-related strategies, plans, and other legislative documents.

The enterprise perspective provides a mechanism to link operational activities into the higher level goals listed above. Figure 8 shows the stereotypes defined in the TNA with respect to the enterprise perspective. This structure is constructed from the TRAK metamodel. A standard or document governs an enterprise goal, while an enterprise aspires to an enterprise goal. This enterprise goal requires capabilities, and a capability can be further deconstructed using the
‘depends on’ relationship into sub-capabilities. Both enterprise goals and capabilities can be quantified by a number of metrics.

In the TNA, there are several types of diagrams that depict subsets of this information. These have been built based largely on the TRAK standard. The enterprise perspective contains only one view named the ‘Enterprise View’ with a set of defined viewpoints, as shown in Figure 9.

9.1.1. TRAK EV-01 enterprise

The purpose of this viewpoint is to identify the various enterprises and organisations within the transport system and how they interrelate. Figure 10 shows the various enterprises and high-level organisational functions performed by the transport cluster. The diagrams contained within these elements provide additional information about how these enterprises are structured.
9.1.2. TRAK EV-02 enterprise goals

EV-02 diagrams from the TRAK standard (Figure 11) identify the long term goals for a particular enterprise as documented in related strategies and plans. A typical transport-related strategy is the *NSW Long Term Transport Master Plan (LTTMP)* which contains eight high-level enterprise goals such as:

- improve quality of service
- improve liveability
- support economic growth and productivity
- support regional development
- improve safety and security
• reduce social disadvantage
• improve sustainability
• strengthen transport planning processes

Each of these eight long-term goals comprises a set of sub-enterprise goals that are documented in the child documents of the LTTMP. This is shown in Figure 12. Each element contains an attribute which indicates where that particular element had come from; for example, the enterprise goal 'Improve safety of the heavy rail network', extracted from 'Sydney's Rail Future: Modernising Sydney's Trains' (June 2012) document.

Figure 11 – [TRAK_EV-02-MU-MD] transport long term goals
Figure 12 – [TRAK_EV-02-MU-MD] Improve safety and security
9.1.3. TRAK EV-03 capability hierarchy

The EV-03 diagrams identify the capabilities needed to meet the enterprise goals in the EV-02 view and show how they are related. These diagrams can also lead into an allocation to concept activities, displaying which operational activities support the capabilities. A sample TRAK EV-03 diagram is shown in Figure 13.

Figure 13 – [TRAK_EV-03-MU-MD] Improve safety and security
9.1.4. ASA EV-01 organisational hierarchy

As the human element is an important part of the system, a set of diagrams have been constructed to help understand the current organisation structure. The ASA has defined the ASA EV-01 diagram for this purpose. As shown in Figure 14, the ASA EV-01 can be used to capture the hierarchy used in organisations, deploying aggregation relationships. This view will require more attention when the transport cluster undergoes a reform or restructure.

![ASA EV-01 organisational hierarchy diagram]

Figure 14 – [ASA_EV-01-MU-MD] TfNSW organisation hierarchy
9.2. **TNA concept perspective**

The concept perspective, also commonly referred to as the operational perspective, defines a generic outline of a system and how it operates so that solutions can be mapped into it for validation and verification. The concept perspective of the TNA is coloured in yellow in the 'model content overview' diagram, as shown in Figure 15. In the latest version of the concept perspective, a physical view connotes the actual configuration of a system, while a functional view signifies the function in question performed by the system. The physical view has been included in the TNA model purely for reference purposes.

![Concept Perspective Diagram](image)

**Figure 15 – TNA concept perspective**

Figure 16 depicts the underlying structure of the concept viewpoint area. Concept activities support capabilities and are conducted by nodes (to ultimately supply that capability). The hierarchies of nodes, concept activities and link to capabilities are all contained within the concept view. It is possible to capture the hierarchies of nodes, concept activities and items using the ‘has part’ relationships.
**Figure 16 – Concept perspective elements and relationships**

The concept perspective contains a total of two views named ‘concept view’ and ‘solution view’, as shown in Figure 17.

**Figure 17 – Concept and solution views and viewpoints**
9.2.1. **TRAK CV-02 concept node**

TRAK CV-02 diagrams focus on the ‘has part’ relationships between nodes. These diagrams provide hierarchy depictions of the physical aspects of the system in a tree-like structure. See, for example, Figure 18.

![Image of TRAK CV-02 concept node diagram]

Figure 18 - [TRAK CV-02] Heavy rail management operational entities
9.2.3. **TRAK CV-04 concept activity to capability**

The TRAK CV-04 viewpoint creates the connection between the capabilities and the concept activities. This particular view allows users to trace to the relevant capabilities in which the concept activities support. A sample TRAK CV-04 diagram is shown in Figure 19.

![TRAK CV-04 concept activity to capability](image)

---

**Figure 19 - [TRAK.CV-04-MU-MD] Improve liveability**
9.2.4. TRAK CV-05 concept activities

TRAK CV-05 is one of the most used viewpoints in the TNA. This view is used to capture the hierarchy of concept activities by showing the breakdown of concept activities into lower level activities. The concept activities are grouped into five main domains:

- **Transport stock** – the system element that moves people or things or both. Concept activities within this domain include:
  - carry and protect passenger, train crew and load
  - appropriate conditions for passenger, crew and load
  - provide access and loading
  - supply energy to operate vehicle
  - accelerate, maintain speed, brake and stop
  - support and guide the vehicle on track or road

- **Exchange infrastructure** – the ability to enter and exit the transport network. Concept activities within this domain include:
  - facilitate commercial use of real estate at stations or stops or both
  - support safe and efficient customer circulation
  - plan facilities for smooth station and stop operations
  - support customer comfort and convenience at stations or stops or both
  - link catchment area and transport network
  - plan stations that promote community value and enhance customer experience

- **Transport network infrastructure** – the path the transport stock takes. Concept activities within this domain contains most of the engineering discipline functions such as:
  - manage electrical power supply systems – transfer electrical energy, protect electrical systems, modify electrical energy, and so on
  - route boundary management – fencing maintenance, vegetation management, level crossing control, traffic boundary management
  - signalling and control system operations – provide a reliable means of communication, ensure safe movement of vehicles, ensure fail-safe operations
  - provide support structure and guide-way for transport stock – provide an exclusive right of way, support external developments, manage civil structures, track system and geotechnical risks
• infrastructure management – telecommunications, signalling, control systems, electrical and track infrastructure management

• provide and manage accessibility

• Communications – monitoring and communication technology infrastructure. Concept activities within this domain include:
  ○ telecommunication services to support the asset
  ○ manage infrastructure for current network requirements
  ○ interface telecommunications with civil infrastructure
  ○ telecommunication services to support the customer
  ○ allow access to the telecommunication network

• Transportation management – the people-centric activities that assist in operating and maintaining the system
  ○ safety management operations
  ○ manage service performance
  ○ manage environment and sustainability
  ○ freight and passenger service operation
  ○ operations control centre – manage customer information, operations, security, manage and maintain operational assets
A sample TRAK CV-05 diagram is shown in Figure 20.

![Figure 20 - [TRAK_CV-05-HR-RS] Rolling stock functional hierarchy]
9.2.5. **TRAK SV-04 solution function**

TRAK SV-04 solution function viewpoint is the lowest-level function in the hierarchy of functions and concept activities. Below this level will link to physical components which are in essence the solutions to achieving these functions. A sample TRAK SV-04 diagram is shown in Figure 21.

![Figure 21 - TRAK SV-04 solution function](image)

**Figure 21 - [TRAK_SV-04-MU-RS] Manage systems that provide appropriate and safe conditions**

9.2.6. **TRAK SV-05 solution function to concept activity mapping**

The TRAK SV-05 is the link between the CV-05 and SV-04 viewpoints. It begins to aggregate the functions into the relevant concept activities. An example is shown below (from top to bottom):

- <<CV-05 Concept Activity>> Provide vehicle communications, monitoring and control
- <<SV-05 Concept Activity>> Allow proper control
- <<SV-04 Function>> Manage systems that provide appropriate and safe conditions
- <<SV-04 Function>> Manage Passenger information, PA and intercom
A sample SV-05 diagram is shown in Figure 22.
9.3. **TNA management perspective**

Several views and diagrams have been developed under the overarching 'management perspective' to help add information that applies across multiple areas of the TNA. The management perspective shown in Figure 23 contains multiple views such as document view, metrics view, and requirement view.

![Figure 23 - TNA management perspective](image)

Each of the views (such as document, metric) in the management perspective contains its own set of viewpoints, as shown in Figure 24.

![Figure 24 - Views and viewpoints within the management perspective](image)
9.3.1. Requirement view

The requirement view in the TNA contains package diagrams, requirement tables and requirement diagrams. Requirement diagrams are common to architecture frameworks that apply to systems engineering applications. These diagrams are used to depict requirements that relate to the business and system and rationale behind their application. To appropriately manage the requirements in the TNA, the four requirement viewpoints were established, as shown in Figure 25. Elements from the concept perspective are used to elicit a generic set of business and system requirements. Figure 26 represents a list of business requirements elicited from a set of concept activities; for example, ‘provide ride comfort’.

<table>
<thead>
<tr>
<th>Requirement Viewpoints</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASA_RV-01 Requirement Hierarchy</td>
</tr>
<tr>
<td>ASA_RV-02 Requirement to Capability/E-Goal</td>
</tr>
<tr>
<td>ASA_RV-03 Requirement to Concept Activity</td>
</tr>
<tr>
<td>ASA_RV-04 Requirement Table</td>
</tr>
</tbody>
</table>

Figure 25 - Requirement viewpoints
Figure 26 - [ASA_RV-03-MU-RS] Appropriate conditions for passenger, crew and load
In addition to Figure 26, requirements can be viewed in the form of a table in the ASA_RV-04 viewpoint (Figure 27) or in the form of a requirement hierarchy in ASA_RV-01.

<table>
<thead>
<tr>
<th>#</th>
<th>Id</th>
<th>Name</th>
<th>Text</th>
<th>Cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>Provide support for standing</td>
<td>The solution shall provide a safe standing position for customers</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Provide seating possibilities</td>
<td>The solution shall provide a comfortable sitting position</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Provide sanitary services</td>
<td>The solution shall provide sanitary services</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td></td>
<td>Provide ride comfort</td>
<td>The solution shall provide a comfortable ride for customers</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td></td>
<td>Provide public address, passenger information, intercabinators</td>
<td>The solution shall provide relevant passenger information systems to inform the intercabinators</td>
<td></td>
</tr>
<tr>
<td>57</td>
<td></td>
<td>Provide clean climate</td>
<td>The [existing] rolling stock vehicle shall provide proper climate for customers</td>
<td></td>
</tr>
<tr>
<td>78</td>
<td></td>
<td>Provide physical security - rolling stock</td>
<td>The solution shall provide physical security for all customers</td>
<td></td>
</tr>
<tr>
<td>82</td>
<td></td>
<td>Provide interior lighting</td>
<td>The solution shall provide interior lighting</td>
<td></td>
</tr>
<tr>
<td>85</td>
<td></td>
<td>Provide external view</td>
<td>The solution shall provide external view</td>
<td></td>
</tr>
</tbody>
</table>

Figure 27 - [ASA_RV-04-MU-RS] Appropriate conditions for passenger, crew and load

9.3.2. Document view

The document view contains three viewpoints: DV-01 document set description, DV-02 document content and DV-03 document interdependencies (Figure 28).

The DV-01 viewpoint is intended to allow co-location of documents through package diagrams. These diagrams present a structure that allows users to easily find standards and various documents, as shown in Figure 29.

Figure 27 - [ASA_RV-04-MU-RS] Appropriate conditions for passenger, crew and load

The document view contains three viewpoints: DV-01 document set description, DV-02 document content and DV-03 document interdependencies (Figure 28).

Figure 28 - Document viewpoints

The DV-01 viewpoint is intended to allow co-location of documents through package diagrams. These diagrams present a structure that allows users to easily find standards and various documents, as shown in Figure 29.

Figure 29 - [ASA_DV 01-MU-MD] TfNSW top level documentation
The DV-02 viewpoint has proved to be a useful way of capturing information contained within a document. The DV-02 is created to capture the relationships between a document and the content extracted from that document, as shown in Figure 30. This provides the context and source of the information and can also be used to perform a direct comparison between similar documents or version of a particular document.

![Figure 30 - [ASA_DV 02-HR-RS] T HR RS 12001 ST document content](image)

The example shown in Figure 30 indicates that not only requirements but also capabilities and enterprise goals from the Long Term Transport Master Plan (LTTMP) can be extracted from a document. The third viewpoint (DV-03), although not currently in use, is a placeholder to represent document interdependencies. While some observations have shown that this is a decreasing trend with many standards aiming to become self-contained, legacy documentation and other areas will still need to make this cross-reference. This articulation of the interdependencies can be extremely valuable to ensure that oversight does not occur and to understand the implications of adopting particular standards or policies.

### 9.3.3. Organisation hierarchy

For information about organisational hierarchy diagrams, refer to Section 9.1.4 of this document.
9.3.4. Metric views

The metric view is one of the latest additions to the TNA. While there are many metrics linked to elements of the enterprise view, it was recently proposed to create a separate area for metric to assist business requirements specification (BRS) or system requirements specification (SRS) writers to introduce a constraint or a measure to their requirement. The metric view is under development and therefore currently blank.

9.4. All views

In 2015, it was recognised that there are a large number of diagrams arranged in a hierarchical organisation that is best viewed from the top level to ensure that the content is viewed within the right context. Therefore it is useful to have a mechanism that directs users to diagrams of interest and to find the appropriate entry points for the various areas (such as the top level 'light rail functional' view). This mechanism could have been provided through the system architecture software's model browser, though it is less intuitive for users who are not familiar with the software. This feature also does not allow guidance between different regions of the model when following a line of inquiry. The all views navigation diagrams are intended to resolve these problems and allow easy movement between diagrams, irrespective of their location.

These navigation diagrams are used to traverse the model and act as an entry point to other views of the TNA. The content of these diagrams are basically references to other diagrams as well as graphics that help structure and present the data. For example, Figure 31 structures a set of diagrams that make up the functional architecture for the heavy rail mode of transport.

To better understand how to navigate the TNA, Appendix C of this document shows a sample walkthrough into multiple perspectives, views and viewpoints.
10. Future direction

The initial focus of the ASA was to develop a functional architecture for all disciplines within the heavy rail mode of transport. This commenced with rolling stock and station precinct buildings for the passenger network. Development of the functional architecture into other disciplines continued and the scope began to expand into other modes of transport. Continuing the development of the existing areas and then expanding the scope across the whole network will result in a framework that provides multiple views of the system that are consistent across all domains.

From the TNA point of view, the TNA has been structured in a way so that it not only supports the heavy rail mode of transport but all the other modes such as light rail, buses, ferries and so forth. The ASA plans to use this multiphase approach to reuse the generic information as much as possible for the other modes of transport. Preliminary work has already been done for light rail in version 1 of the TNA.

As part of the development of the transport network requirements, the validated functional architectures will be used to elicit a generic set of business and system requirements. Since the heavy rail functional architecture is the most mature at this stage, the next tranche of work may focus on eliciting requirements from the heavy rail functional architecture and storing them in the requirement view of the TNA. Performing this work may require the development of
subordinate views within the concept perspective such as 'CV-01 concept need' and 'CV-02 concept node'. This is because a node (also referred to as a logical operational entity) may exhibit a need to perform a concept activity.

In addition to the TNA and network requirements’ future direction, investigation into topic-based writing may take place over the following year; however scope and purpose at this stage are unclear.
Appendix A  The TRAK metamodel

Figure 32 shows the TRAK metamodel as published by the TRAK Steering Group, chaired by the UK Department of Transport. It illustrates the elements used to make the TRAK models. The TRAK views that contain these elements are defined by TRAK viewpoints.

A full description and details of the TRAK metamodel are available from TRAK00002 (https://trakmetamodel.sourceforge.io/).
## Appendix B  Tracing TRAK to other frameworks

Table 1 compares and matches the viewpoints and perspectives of three different frameworks; TRAK, DoDAF and UPDM.

<table>
<thead>
<tr>
<th>TRAK</th>
<th>DoDAF</th>
<th>UPDM</th>
</tr>
</thead>
<tbody>
<tr>
<td>EVp-01: Enterprise Goal</td>
<td>DoDAF CV-1</td>
<td>StV-1 Capability Vision</td>
</tr>
<tr>
<td>EVp-02: Capability Hierarchy</td>
<td>DoDAF CV-2, CV-4, CV-5</td>
<td>StV-2 Capability Taxonomy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>StV-4 Capability Clusters</td>
</tr>
<tr>
<td></td>
<td></td>
<td>StV-5 Capability to Organization Deployment</td>
</tr>
<tr>
<td>EVp-03: Capability Phasing</td>
<td>DoDAF CV-3</td>
<td>StV-3 Capability Phasing</td>
</tr>
<tr>
<td>CVp-01: Concept Need</td>
<td>DODAF OV-1, OV-2</td>
<td>OV-2 Operational Node Connectivity Description</td>
</tr>
<tr>
<td>CVp-03 Concept Item Exchange</td>
<td>DoDAF Operational Resource Flow Matrix</td>
<td>OV-3 Operational Exchange Summary</td>
</tr>
<tr>
<td>CVp-04 Concept Activity to Capability Mapping</td>
<td>DoDAF CV-6</td>
<td>StV-6 Operational Activity to Capability Mapping</td>
</tr>
<tr>
<td>CVp-05 Concept Activity</td>
<td>DoDAF Operational Activity Decomposition Tree – OV-5A</td>
<td>OV-1b Operational Context Description</td>
</tr>
<tr>
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<td>OV-1d Operational Context Use Cases</td>
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<td></td>
<td></td>
<td>OV-5 Operational Activity Model</td>
</tr>
<tr>
<td>CVp-06 Concept Sequence</td>
<td>DODAF OV-6b State Transition Description Model</td>
<td>OV-6c Operational Event Trace Description</td>
</tr>
<tr>
<td>PrVp-01 Procurement Structure</td>
<td>DoDAF PV-1</td>
<td>AcV-1 System of Systems Acquisition Clusters</td>
</tr>
<tr>
<td>PrVp-02 Procurement Timeline</td>
<td>DoDAF PV-2</td>
<td>AcV-2 Program Timeline</td>
</tr>
<tr>
<td>PrVp-03 Procurement Responsibility</td>
<td>DoDAF PV-1</td>
<td>AcV-1 System of Systems Acquisition Clusters</td>
</tr>
<tr>
<td>SVp-01 Solution Structure</td>
<td>DODAF SV-1 Systems Interface Description Model</td>
<td>SOV-1 Service Taxonomy</td>
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<tr>
<td>SVp-02 Solution Resource Interaction</td>
<td>DoDAF Systems Interface Description</td>
<td>SV-1 Resource Interaction Specification</td>
</tr>
<tr>
<td>SVp-03 Solution Resource Interaction to Function Mapping</td>
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<td>SVp-04 Solution Function</td>
<td>DODAF SV-4 Systems Functionality Description Model</td>
<td>SOV-5 Service Functionality</td>
</tr>
<tr>
<td>SVp-05 Solution Function to Concept Activity Mapping</td>
<td>DODAF SV-5a / SV-5b Operation Activity to Systems Function Traceability Matrix Model</td>
<td>SV-5 Function to Operational Activity/Service Function Traceability</td>
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</table>

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<table>
<thead>
<tr>
<th>TRAK</th>
<th>DoDAF</th>
<th>UPDM</th>
</tr>
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<tr>
<td>SVp-06 Solution Competence</td>
<td>DoDAF Systems Technology and Skills Forecast</td>
<td>SV-9 Technology and Skills Forecast</td>
</tr>
<tr>
<td>SVp-07 Solution Sequence</td>
<td>DoDAF System Event Trace Description</td>
<td>SV-10c Resource Event Trace Description</td>
</tr>
<tr>
<td>MVp-02 Architecture Description Design Record</td>
<td>DODAF AV-1 Overview and Summary Information Model</td>
<td>AV-1 Overview and summary information</td>
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<tr>
<td>MVp-03 Requirements and Standards</td>
<td>DoDAF OV-6a Operational Rules Model DoDAF Systems Rules Model DoDAF StdV-1</td>
<td>OV-6a Operational Rules Model SV-10a System Rules and Constraints TV-1 Standards Profile</td>
</tr>
</tbody>
</table>
Appendix C  Navigating the TNA model

The following diagrams (illustrated as a series of steps) show an example of how to navigate the transport network architecture (TNA) model.

On entering the architecture model, you will be directed to the home page where you can start exploring the different perspectives, views and viewpoints as described throughout this document.

The following diagram in particular provides the following information for the TNA model; title, version, issue date, brief background, purpose, scope, caveats, and a link to this document published on the ASA website.

Before entering the TNA model, it is important to note that this model is still a work in progress and shall not be used as the single source of truth when making planning and design decision on transports. The TNA model shall only be used as a decision support tool to prompt the development of requirements on transport projects.

Step 1 – Enter the TNA by clicking ‘Enter’

For more information, please read T MU AM 06011 TI Transport Network Architecture
Step 2 – Browse the 'Transport Long term Goals' through the 'Enterprise Perspective'

The diagram in step 2 is the Home page for the TNA model. This diagram allows the user to navigate to various parts of the model under different perspectives and views. The 'enterprise perspective' contains enterprise goals and capabilities. The 'concept perspective' contains concept activities, functions and some physical items whereas management perspective contains documents, organisation hierarchy and most importantly requirements.

If you are involved in writing high-level business needs and requirements for any transport project, click on the highlighted red box in the diagram.
Step 3 – Click 'Improve Liveability' diagram icon

This diagram shows the highest-level enterprise goals. Each box could be used as a high-level business need or requirement in a BRS. For example, the solution shall improve liveability. If the user wishes to see how liveability can be improved, click on the diagram icon in the box outlined in red, see the following (not to be confused with the red 'Home' box).
Step 4 – Click 'Allocation to Capability' diagram icon

This diagram shows how the enterprise goal 'improve liveability' could be achieved, based on various reference documents as shown below. Each enterprise goal here could be used to write a business requirement to support the requirement mentioned in step 3. For example, the solution shall integrate with other modes of transport.

The next step shows how the enterprise goal 'improve liveability' is currently being achieved by a set of capabilities. Click on the red box in 'Allocation to Capability' box below.
Step 5 – Click ‘Allocation to Concept Activities’ diagram icon

This diagram shows TfNSW's ability to carry out a particular kind of action in order to achieve the enterprise goal 'improve liveability'. TfNSW tries to improve liveability through the capability in 'providing convenient services' which could also be used as a business need or requirement. For example, the solution shall provide convenient services. These capabilities are then allocated to a set of concept activities which are high-level system activities or functions performed by the transport network. Click on the red box in ‘Allocation to Concept Activities’ box; see the following.
Step 6 – Click on ‘<Concept Activity> Accelerate, maintain speed, brake and stop’

This diagram shows the high-level system activities that support the capabilities shown in step 5. The main purpose of this diagram is to show the linkage between the enterprise view (that is, the ‘what’) and the concept view (the ‘how’). For example, in achieving the capability ‘providing services to meet current & future capacity’, TfNSW may ‘plan for heavy rail services’, ‘supply energy to operate vehicle’, ‘allow vehicles to run at demanded frequencies’, ‘accelerate, maintain speed, brake and stop’ and so on.

Click on the red box outlining the concept activity ‘Accelerate, maintain speed, brake and stop’ for more information about this activity.
Step 7 – Click on 'Allocation to Functions' diagram icon

The following diagram shows the sub-concept activities and relevant nodes that support the high-level system functions 'Accelerate, maintain speed, brake and stop'. The nodes are defined by TRAK as logical operational entities which in this case are the high-level physical items that are broken down to lower-level physical items. The nodes and physical views are briefly mentioned in step 11 and currently under development for TNA model v2.0.

It is important to note that this diagram ID is [TRAK_CV-05-MU-RS] which means that it is multi-modal and rolling stock-specific. The information contained in this diagram is a result of the higher level heavy rail and light rail rolling stock vehicle functions. Click on the red box outlining the 'Previous (light rail)' diagram icon to navigate up to the parent diagram where 'accelerate, maintain speed, brake and stop' is one of the concept activities for a light rail vehicle.

Otherwise click on the red box outlining the 'allocation to function' diagram icon to see the child system functions that support these concept activities.
Step 8 – Lowest level of functions for 'Accelerate, maintain speed, brake and stop'

This diagram shows the breakdown of system functions to support the overarching concept activity 'Accelerate, maintain speed, brake and stop'. The functions in this diagram can be used as requirement on projects as part of an SRS.

Example system requirements:

- the new rolling stock vehicle shall provide wheel slip protection
- the propulsion system shall be configured according to operational modes
- the vehicle shall acquire propulsion demand from driver through in cab controls
Step 9 – Light rail stops functional hierarchy. Click on ‘Previous’ diagram icon

This diagram shows the highest-level concept activities for a light rail vehicle. By clicking on each concept activity, you will be directed to a lower level set of functions that support the parent concept activity. Information contained in this diagram can be used to define business and system requirements as part of a BRS or SRS.

**Business requirement:** the new light rail vehicle shall provide appropriate conditions for all passengers during normal operation

**System requirement:** the light rail vehicle fleet shall operate at an acceptable noise output of no more than \[x\] when operating on the light rail network
Step 10 – Currently incomplete 'Light Rail Functional View'. Click on 'Previous' diagram icon

The diagram below is a typical navigation type diagram where the user can navigate to other diagrams that may interest them. This diagram shows the five domains that are specific to light rail as described in Section 9.2.4. Depending on the type of project, the user is able to navigate through each domain for the following information:

- light rail vehicle – for all light rail vehicle functions
- light rail stops – for functions relating to light rail stops
- light rail route – for functions relating to power supply, light rail boundary, signalling and control, support structure, infrastructure and accessibility
- communications – for all operational technology and telecommunication-related functions
- management – safety, environment, service performance and operations control centre

As described in step 8 and step 9, these functions can easily be written as a requirement to form part of a BRS or SRS. Click on the ‘previous’ model content overview diagram icon (outlined in red) to go to the parent diagram which is also the home page.
Step 11 – Click on 'Requirement view' diagram icon

The user returns to the home page to navigate through another view. It can be seen in concept perspective that there is a functional and physical view. The physical view directs the user into the nodes and physical elements as mentioned in step 7. These elements are considered to be the solution to achieving the functions in the functional view. For example, to provide acceleration, a running gear and propulsion system may be used to achieve this function.

Requirements that are extracted from the enterprise and concept perspectives are placed in requirement view diagrams. Click on the requirement view diagram icon in the red outlined box.
Step 12 – Click on 'Requirements Package – Transport stock'

The following diagram is another navigation-type diagram where users can navigate through different requirement packages. It was previously mentioned in Section 10 of this document that developing the transport network requirements is part of the next tranche of work. Those elicited requirements will reside in the following packages. To date, only the transport stock requirements have been developed for heavy rail vehicle.

To enter the requirement hierarchy view, click on the red outlined package folder named 'requirements package – transport stock'.
Step 13 – Click on 'Vehicle communications, monitoring and control' diagram icon

The following diagram shows the separate groups of requirements from four modes of transport, heavy rail, light rail, bus vehicle and ferry vessel. As previously mentioned, only the heavy rail vehicle requirements have been developed to date. Each diagram icon in the figure below directs the user to the highest level requirements specific to the name of that diagram icon; for example; vehicle communications, monitoring and control. Each diagram icon will direct the user to the business requirements in that particular area.

To view the requirements relating to 'vehicle communications, monitoring and control', click on the red outlined box below.
Step 14 – Click on ‘Allocation to Requirements’ diagram icon and user will be directed to the list of requirements that relate to vehicle communications, monitoring and control

The following diagram shows an example of how requirements (particularly business requirements) are elicited from the concept activities which make up the functional view. Since these are generic business requirements, only the ‘id’ and ‘text’ requirement fields are included. The user is expected to use the requirements fields as described in T MU AM 06004 ST Requirements Schema.

Therefore information contained in this diagram can be used to write the business requirements for a rolling stock vehicle project. The business requirements in this diagram are allocated to system requirements which can be viewed by clicking on the diagram icon ‘allocation to requirements’. 
Step 15 – Click on 'Requirement Table' diagram icon and user will be directed to the list of requirements in a table form

The following diagram (although unreadable) shows the hierarchy and traceability of business requirements to system requirements. The purpose of this diagram in the model is to prompt the user when writing requirements in a BRS or SRS. The user can also view these requirements in the form of a table as shown in step 16.

To go back to the home page, click on the 'Home' diagram icon in the red coloured box (step 17).
Step 16 – Requirement table for vehicle communications, monitoring and control

The following diagram (though again unreadable) shows all the 'vehicle communications, monitoring and control' business and system requirements in the form of a table. This diagram in particular is a useful view for users to help identify relevant requirements for a given transport project.

<table>
<thead>
<tr>
<th>#</th>
<th>Related to</th>
<th>Required by</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Keep vehicle view and operation staff informed on state of vehicle and systems</td>
<td>The solution should keep vehicle view and operation staff informed on the state of the vehicle and systems</td>
</tr>
<tr>
<td>2</td>
<td>Acquire information to be displayed</td>
<td>The solution shall acquire information to be displayed</td>
</tr>
<tr>
<td>3</td>
<td>Manage information access</td>
<td>The solution shall manage information access</td>
</tr>
<tr>
<td>4</td>
<td>Ensure clarity of information</td>
<td>The solution shall ensure clarity of information</td>
</tr>
<tr>
<td>5</td>
<td>Enable switching between different types of display screens</td>
<td>The solution shall enable the switching between different types of display screens</td>
</tr>
<tr>
<td>6</td>
<td>Ensure rapidity of information under degraded conditions</td>
<td>The solution shall ensure rapidity of information under degraded conditions</td>
</tr>
<tr>
<td>7</td>
<td>Provide information</td>
<td>The solution shall provide information</td>
</tr>
<tr>
<td>8</td>
<td>Provide operation relevant information</td>
<td>The solution shall provide operation relevant information</td>
</tr>
<tr>
<td>9</td>
<td>Provide operational command information</td>
<td>The solution shall provide operational command information</td>
</tr>
<tr>
<td>10</td>
<td>Provide diagnostic information</td>
<td>The solution shall provide diagnostic information</td>
</tr>
<tr>
<td>11</td>
<td>Provide maintenance information</td>
<td>The solution shall provide maintenance information</td>
</tr>
<tr>
<td>12</td>
<td>Provide passenger information</td>
<td>The solution shall provide passenger information</td>
</tr>
<tr>
<td>13</td>
<td>Provide ticket information</td>
<td>The solution shall provide ticket information</td>
</tr>
<tr>
<td>14</td>
<td>Provide vehicle operator and driver information</td>
<td>The solution shall provide vehicle operator and driver information</td>
</tr>
<tr>
<td>15</td>
<td>Provide vehicle specific radio information</td>
<td>The solution shall provide vehicle specific radio information</td>
</tr>
<tr>
<td>16</td>
<td>Provide vehicle status information to the driver</td>
<td>The solution shall provide vehicle status information to the driver</td>
</tr>
<tr>
<td>17</td>
<td>Provide vehicle radio communication</td>
<td>The solution shall provide vehicle radio communication</td>
</tr>
<tr>
<td>18</td>
<td>Manage vehicle network operation</td>
<td>The solution shall manage vehicle network operation</td>
</tr>
<tr>
<td>19</td>
<td>Manage vehicle network access</td>
<td>The solution shall manage vehicle network access</td>
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<tr>
<td>20</td>
<td>Manage fare data</td>
<td>The solution shall manage fare data</td>
</tr>
<tr>
<td>21</td>
<td>Inaugurate vehicle network</td>
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</tr>
<tr>
<td>22</td>
<td>Define vehicle configuration</td>
<td>The solution shall define vehicle configuration</td>
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<td>23</td>
<td>Determine vehicle topology and configuration</td>
<td>The solution shall determine vehicle topology and configuration</td>
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<td>Manage leading vehicle information</td>
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</tr>
<tr>
<td>25</td>
<td>Provide construction for guided elements</td>
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</tr>
<tr>
<td>26</td>
<td>Distribute vehicle topology and configuration</td>
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<td>27</td>
<td>Manage vehicle Operator Nodes</td>
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<td>Manage battery protection mode</td>
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<td>Manage in-run mode</td>
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<td>33</td>
<td>Manage starting from charged battery</td>
<td>The solution shall manage starting from charged battery</td>
</tr>
<tr>
<td>34</td>
<td>Manage starting from flat battery</td>
<td>The solution shall manage starting from flat battery</td>
</tr>
</tbody>
</table>
**Step 17 – 'Home' page of the TNA model**

This is the 'Home' page of the TNA model where users can continue to navigate through other perspectives, views and viewpoints. The very top right hand corner of this diagram shows two hyperlinks named 'Here'. The first hyperlink directs the user to the 'TNA diagram identifier scheme' as shown in Figure 4 and the second hyperlink directs the user to a basic list of terms and definitions used throughout the model.
Appendix D  Downloading the TNA model

The TNA model is uploaded on the ASA website and can be set up in a few simple steps.

**Step 1:** download the .zip file named 'T MU AM 06011 MO Transport Network Architecture Model v1.0.zip'. If your browser prompts you to 'open', 'save' or 'cancel' the action, click on the 'save' option and choose a location on your local drive.

**Step 2:** once downloaded, create a folder in your desired drive (preferably a local drive for optimum performance). For example, C:\Program Files\ TNA Model v1.0

**Step 3:** extract the downloaded .zip file to this new location (this may take up to two hours)

**Step 4:** in the extracted files, click on the HTML file name 'Web publisher TNA Model v1.0' and open in your Internet Explorer browser. Unfortunately Firefox, Chrome and other browsers will not work. If an issue appears in Internet Explorer, you may be required to 'allow' changes to your browser or close the page and try again.

**Step 5:** the image shown in Figure 33 should appear when clicking on the HTML link. Refer to Appendix C for navigation support.

![Figure 33 - 'Welcome to the Transport Network Architecture v1.0' screen](image-url)