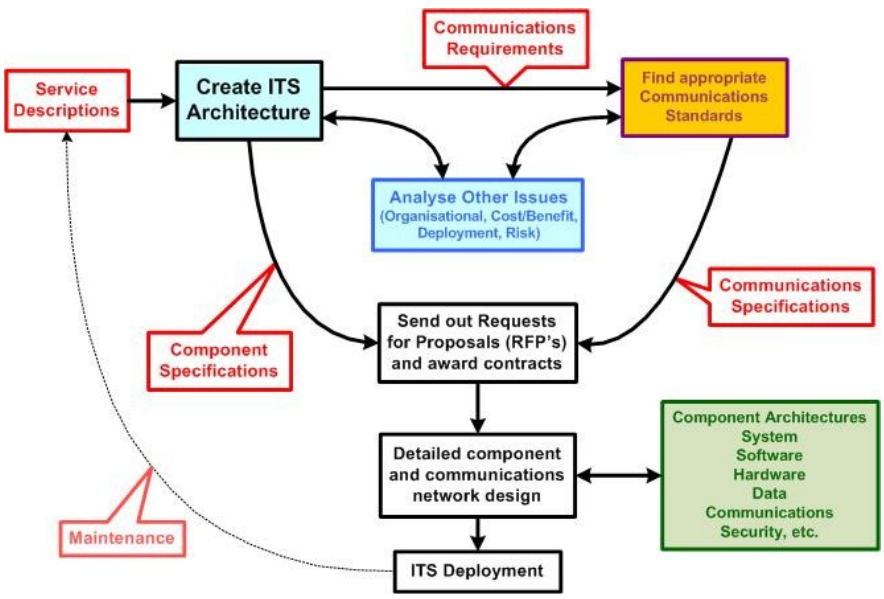
ITS ARCHITECTURE

Stakeholders involved in deploying ITS require an appreciation of how the ITS enabling technologies can work together as a system. Not only is it important to secure the necessary performance of the component systems individually, but it is also necessary to ensure that they interface with one another effectively, and integrate them together as a total system.

An ITS Architecture is a conceptual framework (or structure) to guide the deployment of ITS. It is a formal specification of requirements that defines in detail:

- the functions to be performed by the ITS deployment (the user services – such as travel planning, traffic and emergency management, road pricing)
- the physical components needed to deliver these functions (such as roadside equipment, vehicle based control systems, control centre workstations)
- the interfaces and communications necessary to allow exchange of data and information between the physical components
- stakeholders' roles and responsibilities in relation to the ITS deployment

ITS architecture provides a rational basis for specifying the design of equipment and performance requirements – which is necessary for procurement, installation and the development of operational procedures. The architecture is not a definitive design but is a functional representation of the ITS deployment which will be developed into a detailed design taking account of choices available – for equipment, software systems and other technologies. The role of ITS architecture in the ITS implementation process is shown in the diagram below.



The use of ITS architectures in the ITS implementation process

The discipline of developing an architecture allows stakeholders to gain an appreciation of the issues associated with ITS deployments, how they will work in practice and what organisational implications they will have. It makes it possible to provide a view of what the ITS services will look like to key stakeholders, including service users. Creating an ITS architecture enables stakeholders to understand better their various perspective in relation to an ITS deployment - such as:

- the organisational structure required for its operation
- their interdependencies, roles and responsibilities
- a provisional list of likely costs
- an estimate of the benefits that will be provided
- the identification of the risks involved and how they can be mitigated
- essential features to be included in the deployment plan

All this can – and should – be done before work begins to procure, design, develop and deploy any of the components and communications that will be required. An important benefit of creating the ITS architecture is that many modifications to the design of the ITS implementation can be anticipated as a result of the systematically working through the requirements. This means that the need for changes can be identified and accommodated at an early stage in the implementation process which means they can be achieved at much less cost than if they were made later on, when some parts have been designed, produced, tested and installed.

An ITS architecture can be created for any road transport agency that is planning an investment in ITS for any geographic area, such as a nation, region, state, county, province or city. The ITS architecture will be based on a close analysis of how the chosen services are to operate together and interface with one another, leading to a set of high-level statements about the system requirements that are independent of the final design and technology choices.

Examples of the services that ITS can be used to provide for road network operations are:

- real-time monitoring of traffic conditions and journey times across the network
- rapid incident and accident detection with systems for emergency response
- traffic control, sometimes integrated with bus operations or dynamic (traffic responsive) route guidance or parking management
- monitoring local weather conditions, especially snow and ice, high winds at exposed locations, heavy rain, flooding and poor visibility (fog or blown sand)
- provision of information to drivers and travellers via roadside and bus stop VMS
- provision of information to the public via the internet and media organisations
- preparation of network management and statistical information for longer term planning purposes

In the past, ITS deployments were often installed to provide just one or two services for travellers and the movement of goods on the road network. Most of these services worked independently without any communications or data sharing between them. The continuous evolution of ITS has meant that its stakeholders have come to expect that a number of often complex services to manage, gather data and to provide information about the road network can be operated simultaneously within an ITS implementation. While there are risks of conflict between what is needed to provide these services, there are significant opportunities to maximise benefits by integrating them so that they work in synergy. ITS architecture (or system architecture for ITS to use its more correct name) provides the best tool for planning, defining, and integrating all the things needed to create and deploy, or implement ITS so that a combination of several services can be provided.

SHARED VISION

The development of an ITS architecture usually begins with a consensus building process involving multiple stakeholders focused on the ITS-based services that are to be provided. Thus, the resultant architecture represents a consensus among the users, service providers, and transport agencies expressed in common terms, definitions, boundaries, priorities and expectations among the stakeholders who will later be making independent, but now consistent and mutually supportive, decisions.

In summary the ITS architecture will define, for all concerned the physical entities and the data flows that connect them together to form an integrated system. ITS architecture analysis also provides support for the planning and implementation of integrated ITS, including a deployment programme, an organisational viewpoint, cost/benefit and risk analysis studies.

STAKEHOLDER DRIVEN

ITS architectures are developed from a set of user needs and user services defined through consultations with users and stakeholders. Thus, the architecture ensures that the ITS to be implemented is responsive to the needs of all stakeholders, rather than implementing technology for technology's sake.

PROMOTION OF ITS STANDARDS DEVELOPMENT

The ITS architecture will also show clearly and unambiguously the key processes which require standardised interfaces, especially for communications and data exchanges. It is common practice for the physical interfaces between architecture subsystems to be aligned with ITS and industry standards. By defining the different physical entities and the data that has to flow between them, the architecture provides the context for the identification of the most appropriate standards. Based on the interface definitions and an analysis of operational needs, user requirements and hardware/software specifications, the architecture can help identify whether existing standards can be used or if new standards need to be developed at local, regional, national, or international level.

PROVISION OF COMMERCIAL BENEFITS

The design and implementation of standardised ITS components and subsystems in conformance with the ITS architecture will stimulate an open market in equipment and software supply, permit economies of scale, ensure consistency of data and information, encourage investment, and help to ensure interoperability.

RISK MANAGEMENT

A good ITS architecture will consider failure modes and support logical steps to achieve graceful degradation of system performance under abnormal conditions. It will also identify transport policies that need be out in place and any assumptions made about who plays what role in the ITS implementation. This allows joint decisions between partners to be made in concert, reducing the risk of one organisation making wrong guesses as to what other organisations are going to do. By facilitating the identification of the most appropriate standards to be used, the ITS architecture also reduces the risk of de facto or proprietary standards perpetuated by the dominant manufacturers.

LINKING ITS TO THE TRANSPORT PLANNING PROCESS

ITS needs to be integrated into the local or regional transportation plan. An ITS architecture supports this integration by enabling all involved to identify the intended relationships between ITS and conventional transportation plans and solutions. It can also add substance to those plans through the definition of what is required to provide which services and the priority for their implementation.

PROVIDING A BASIS FOR SYSTEM DEVELOPMENT

ITS architectures are used to describe how user services should be provided. This includes the data to be collected, what processing the data will need, where that processing should take place, what data should be shared between the components, plus where and when the resulting information is to be made available to users, other ITS deployments and vehicle fleet and logistics managers. In this way the architectures provides a versatile platform from which component, communications and software can be developed.

PROVIDING A FRAMEWORK FOR FUTURE EXPANSION

ITS architectures provide a framework for system expansion and technological upgrades so that systems can be adapted as stakeholder expectations change and ITS technology evolves. New services or wider geographic coverage can be added without expensive re-engineering or retrofits, provided always that the development is compatible and consistent with the architecture. A completely new ITS user service or a major revision to the service specification will most likely require a re-evaluation and modification to the architecture.

WHAT IS ITS ARCHITECTURE?

The term "ITS architecture" literally means, "System Architecture for Intelligent Transport Systems". As a system architecture it provides a view of how an Intelligent Transport System (ITS) implementation will look from a system design perspective. ITS architectures are primarily about data exchange and the control instructions that pass between the different ITS components and the external interfaces (operators, stakeholders and other systems). It needs to reflect the real-world constraints that operate on transport agencies and the requirements these impose on the ITS implementation. Examples are interoperability between the participating agencies and the retention of information control by the respective agencies.

An ITS architecture may show where existing organisational structures need to be modified and changed – perhaps quite radically – in order to deliver the desired ITS services. An example is a traffic control centre (TCC) that may need to exchange data with another TCC or a traveller information centre (TIC), possibly across national or language boundaries. Defining the content and minimum performance specification for this transaction matters a great deal. The ITS architecture enables the performance specification to be defined to achieve the required level of interconnection and interoperability. The choice of which specific technologies are best to use in response is a matter for the system designer.

It is not possible to present a complex system in a way that can convey all the information about the system in an understandable manner. This is reflected in an ITS architecture, where multiple viewpoints, depicting different levels of detail and different types of information are used. These viewpoints might include:

- the logic (or functionality) of the system describing how various items of data should flow and be processed (the “logical” or “functional” viewpoint)
- how the ITS functionality will reside in the physical components of the system (the “physical” viewpoint)
- what communications are needed between the physical components – and between the outside world and the physical components (the “communications” viewpoint)
- how the system components, communications and responsibilities are to be assigned to providers and recipients of the ITS services (the “organisational” viewpoint)

Along with development of an architecture for ITS there are other analysis requirements to consider – among them:

- how the components and communications might be deployed (the deployment plan)
- what the costs of deployment are likely to be, and how these will be off-set by benefits (a cost/benefit analysis)
- a study of the risks affecting the whole implementation and delivery of the ITS services (a risk analysis)
- It is often important to define the system boundary to show what is outside the specific ITS implementation but important for some of the functional components - for example the financial institutions, such as banks, in the case of toll payment or electronic ticketing

LEVELS OF ITS ARCHITECTURE

ITS architectures can be divided into two levels: high-level architectures and low-level architectures. This is not something that is peculiar to ITS – the distinction applies to the use of system architectures in general.

In the context of Intelligent Transport Systems, a high level architecture is the conceptual design that defines the structure and/or behaviour of the system. It specifies the functionality needed to provide ITS user services – the specifications are technology independent and the selection of individual components and communications are open. This technology independence means that suppliers have freedom to choose a technical solution that is most appropriate for the client, whilst still complying with the overall architecture.

Low-level (or component) architectures, by contrast, contain the actual designs for hardware, software, data exchange and communications. They define more narrowly the technologies required including the use of ITS standards. A low-level architecture could be developed by the commissioning body, if they have the expertise, but it is more common for design specifications to be developed from a high-level architecture by the systems integrator or system supplier.

HIGH-LEVEL ITS ARCHITECTURES

High level ITS architectures are developed to ensure that component systems can be successfully integrated and that the ITS deployment satisfies certain objectives – namely it:

- is planned in a logical manner
- meets the desired performance levels
- is easy to manage, maintain and extend
- delivers the desired performance and satisfies user expectations

They have the following characteristics:

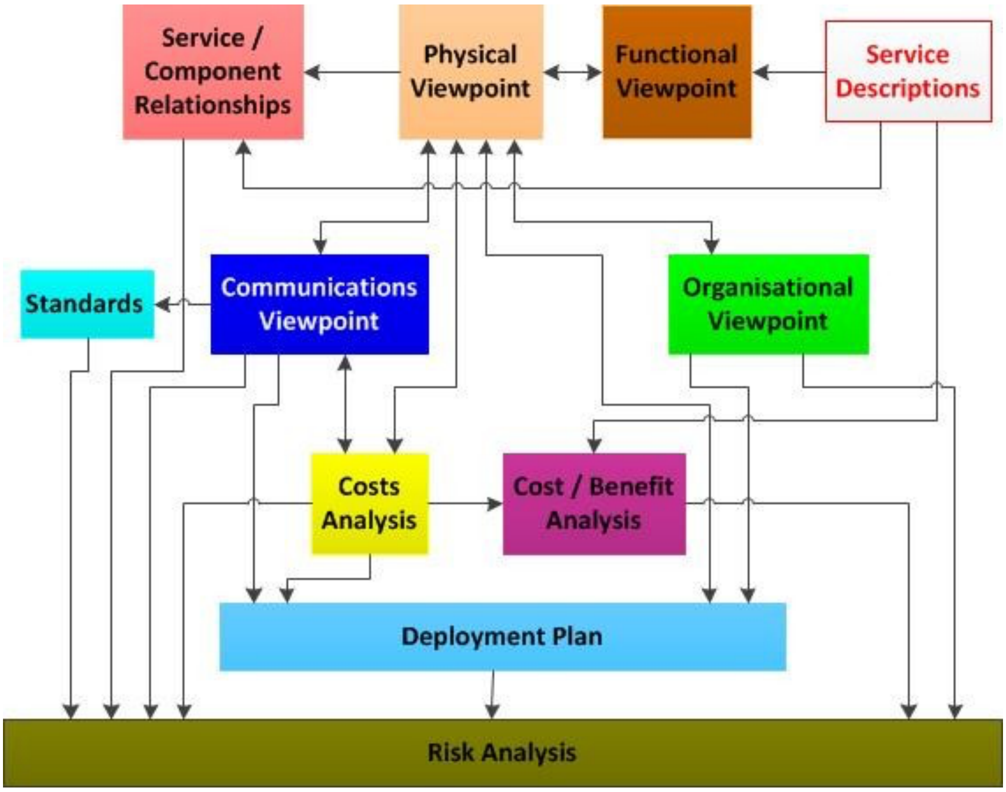
- they describe the function, role and performance requirements of the components and the communications links that enable data exchange;
- they take account of the world outside the specific ITS deployment which will consist of some or all of the following:
    - other systems
    - users of ITS services – for mobility of people and goods
    - system operators – who manage and maintain the components and communications
    - they can often highlight where new technology may be needed and make the case for carrying out research

The creation of a high level ITS architecture with optimal system configuration requires the analysis of a number of different – but crucial – aspects of the proposed deployment, as follows:

- a logical (or functional) viewpoint – what functionality is needed to deliver the services that the ITS architecture supports?

- a physical viewpoint – what system components are needed to deliver the required functionality, and how can these components be grouped together and co-located?
- a communications viewpoint – how does the choice and distribution of functionality in system components and component locations impact on the overall communications requirements?
- an organisational viewpoint – what organisational structure is needed to manage and operate the ITS implementation and how does this fit in with what already exists?
- a deployment plan – how are components and communications to be deployed, taking account of how many existing system components can be re-used?
- a cost/benefit analysis – to estimate the cost of supply and installation of components and communications, offset against the value of benefits from the deployment of ITS
- a risk analysis – to evaluate the areas of risk associated with the deployment, and who will be responsible for their mitigation

The relationship between different system viewpoints and other important aspects of ITS deployment is illustrated by the diagram below.



Relationships between different ITS architecture viewpoints and other aspects of ITS deployment

The relationships shown in the diagram are bi-directional to illustrate how results from one one aspect may influence another. For example, as a result of creating the communications and/or organisational viewpoints it can sometime be necessary to modify the physical viewpoint.

To gain maximum benefit from a high-level architecture it should be developed before any work is done to procure the components and communications needed for the ITS deployment.

LOW-LEVEL ITS ARCHITECTURES

Low-level (or component) ITS architectures contain the actual designs and specifications for hardware, software, data exchange and communications. They define more narrowly the technologies required including the use of and the ITS related standards that are to be used particularly for interfaces and communications. A low-level architecture could be developed by the commissioning body, if it has the expertise, but it is more common for design specifications to be developed from a high- level architecture by the systems integrator or system supplier and may not always be in the public domain.

THE HOUSE BUILDING ANALOGY

There is an analogy between the different levels of ITS architecture and the architecture for a house. In both cases the architecture may have to be expressed in various forms to suit different audiences. For the house buyer, the architecture is initially used to show how the completed house will appear and the floor plan, for example room sizes and where the toilets are located. Once the homeowner is satisfied, more detail is added so that the construction workers are provided with drawings of walls, beams and columns including their precise dimensions. Similarly, the system architecture for an ITS deployment may be expressed in various forms that are mutually consistent. High-level ITS architecture provides stakeholders with views of how the ITS implementation will appear to them. Low-level ITS architectures expand this to include the technical details that enable equipment suppliers and system integrators to implement the services. The selection of a particular architectural form depends on how far the ITS concept has ben developed and the needs of the audience at hand. The idea of multiple architectural forms is consistent with the multiple viewpoints in the IEEE standard 1471-2000, “Recommended Practice for Architectural Description of Software-Intensive Systems.”

ADVICE TO PRACTITIONERS

There are two types of high level ITS architecture in common use around the world – which offer two basic but different approaches – a framework architecture and a ‘model’ architecture – both of which provide a basis for the development of ITS architectures that can be adapted to suit particular ITS implementations. Some of these ITS architectures can be specific to a class of ITS applications. This is because they support implementation of a specific service, such as traffic control centres, car park management, or public transport fleet management.

FRAMEWORK ITS ARCHITECTURES

A framework ITS architecture will use a set of user-led service specifications for different ITS applications that provide a flexible basis for further refinement and development. A framework approach is particularly suited to circumstances where a ‘top-down’ universal approach is not feasible. A framework ITS architecture provides the basis for stand-alone ITS master plans to be developed at the appropriate level (national, regional or local). It can also facilitate cross-border integration and an open market for interoperable ITS services and equipment. The best known example of a framework

ITS architecture is the European ITS Framework Architecture (the FRAME Architecture. A number of countries are using the FRAME Architecture as the starting point for their own national ITS architecture developments – these include Australia, Austria, Czech Republic, France, Hungary, Italy and Poland.

Framework ITS architectures have the following advantages:

- it makes it possible to achieve the harmonious integration of systems by defining where common standards, norms and practices can be used
- it prompts the resolution of important issues - such as stakeholder relationships and responsibilities for communications infrastructure provision
- they can be easily developed and adapted to provide a framework ITS architecture in different national contexts
- users can expand a framework ITS architecture to support additional services
- they can be used to develop low-level ITS (or component) architectures that are adapted for particular ITS implementations – giving users the freedom to create their own component configurations and specify the associated communications networks
- they can be used to explore alternative component configurations and associated communications networks - making it possible to investigate the options leading to an optimum ITS architecture for a particular deployment

‘MODEL’ ARCHITECTURE

Many regions of the world have developed ‘model’ ITS architectures that are adapted to the needs and requirements of their region and institutional arrangements. They are generally more prescriptive in how ITS deployments must be rolled out when compared with a framework ITS architecture. They often contain a physical viewpoint that will define the components used to deliver the services the architecture is able to support. For example the USA’s National ITS Architecture is fixed and its use is obligatory if federal financial support for ITS deployment is sought. It defines:

- the functions of the system and sub-system components
- where these functions reside (at the roadside, in a traffic management centre, or in a vehicle)
- the interfaces and information flows between subsystems
- the communications requirements for the information flows in order to address the underlying user service requirements
- where standardisation of equipment, interfaces and communications at the national level will bring benefits

ADAPTING ITS ARCHITECTURES

A framework ITS architecture and a ‘model’ ITS architecture both provide a structure (or template) from which ITS architectures adapted for particular ITS deployment can be generated. This allows the user the flexibility to tailor the architecture for specific deployments without losing the benefit of its common features - such as the interfaces for system components and communications. Standard interfaces are very important for consistent systems integration and will have greater importance in the future with the advent of cooperative systems ("C-ITS" for short, and known as "connected vehicles" in the USA). This is because of the need for services to be delivered in the same way, everywhere within a region, for example the USA, Europe, Australia and Japan. They make the exchange of information possible at an affordable and effective level.

ITS architectures that are adapted and customised from a *framework ITS architecture* have the following characteristics:

- they can either be used for a particular ITS implementation or as the basis for a series of ITS implementations that use some or all of a common set of functionality (such as regional or urban ITS deployments)
- it is possible to modify the content and add functionality to support additional services before defining the physical viewpoint
- although adding additional functionality is not difficult, it is often advantageous to enlist the help of specialist consultants
- a tool will need to be provided to enable the framework ITS architecture to be adapted and this can simplify its use and application

The FRAME architecture is the best known examples of a framework ITS architecture being used as the 'master" for regional and urban ITS deployments across Europe and other countries, as well as European research projects.

ITS architectures that are customised from a *'model' ITS architecture* have the following characteristics:

- they can either be used for a particular ITS implementation or as the basis for a series of ITS implementations that use some or all of a common set of components and communications networks (such as regional or urban ITS deployments)
- the content is more restricted in terms of its functionality although there may be limited options for varying the component configuration – for example the options for the communications network are restricted to what is compatible with the common specifications
- as a result of the content being restricted, a 'model' ITS architecture cannot be easily expanded by its users to include previously unsupported services – this has to be done by specialist consultants
- if not already available, a tool will need to be provided to enable the 'model' ITS architecture to be adapted and this can simplify its use and application

The US National ITS Architecture is probably the best known examples of a 'model' ITS architecture, being used as the 'master' for regional and urban ITS deployments in the USA, Canada, Chile, Israel and other countries.

WHICH TYPE TO USE?

The choice of which particular ITS architecture development approach to use is dependent on the ultimate objective of the responsible authority or organisation – and will depend on how the ITS architecture is to be used and what is to be the starting point for its creation. In some cases the use of a 'model' ITS architecture is mandatory. For example in the USA, federal financing for ITS deployments is conditional on using of the National Architecture.

A framework ITS Architecture is generally more flexible than a 'model' ITS architecture – though both can be expanded to include extra and/or alternative services. Since framework ITS architectures are not prescriptive they can facilitate the search for an optimum component/communications solution to an ITS implementation. Using a framework ITS architecture requires some training from experts since its users need to understand the ITS architecture creation process and how to use it. A 'model' ITS Architecture is the least flexible since it contains restricted component configuration and communications specifications. But if no changes to the supported services are needed, they are often easier to use and do not require its users to be expert in the creation of an ITS architecture.

For economies in transition it is important to go back to basics to understand the scope for ITS to improve local transport problems and respond to user needs. These must be fully reflected in the ITS architecture's design and specifications. This is necessary so that ITS deployments are planned and well suited to the local context. It should be noted that a 'model' ITS architecture from one region may require considerable modification to adapt it so that it can be suitable for use elsewhere in other implementations of ITS.

DEFINITIONS

ITS Architecture practitioners use many terms - a few are used more frequently than others. These include "component", "data", "information", and "communications" and it is necessary to make sure that everyone has the same understanding of how they are used. In addition, practitioners need to understand the difference between "logical" or "functional architecture" and "physical architecture".

COMPONENT

When considering an ITS Architecture, a "component" is a generalised term used for any constituent part of any ITS implementation that can be provided as an individual item. It can be considered to be a "building block" from which ITS implementations are assembled. It can be created from one or more "bits" of hardware or a combination of hardware and software. Sometimes a combined set of components will be called a "sub-system" of which there may be several in one ITS implementation.

DATA AND INFORMATION

Data about what is happening in the world outside that is relevant to the ITS implementation, arrives from many sources. It can represent the presence of a vehicle, data about a trip that a traveller wants to make, or details of goods and the origin and destination of their movements. The data can also be provided by other systems - such as data about the weather or details of services provided by non-road transport modes.

Information is the result of data that has been processed by one or more components within the ITS application. It can be traffic flow rates, traffic conditions, a trip plan, or details about a goods movement. It can also be the content of a variable message display and the "red/amber/green" indications at traffic signals.

DATA COMMUNICATIONS

The term "data communications" or sometimes "data communications link" is the term given to the mechanism through which data or information is transferred from one component to another - or between a component and something outside the ITS implementation. It can consist of one or more transmission media such as physical cable, wireless, microwave or infra-red - although their specific use may not be defined in the ITS architecture. Communications between people are enabled through an interface provided by a specialist component. For example an operator interface may provide access to several ITS services or traveller information may be provided by a variable message display.

LOGICAL ARCHITECTURE OR FUNCTIONAL VIEWPOINT

The logical architecture or functional viewpoint depicts the functions of the ITS deployment and the associated data flows that take place between the internal components and those that link externally to people, data sources and other systems. This is defined in the formal descriptions of the services. Its development is used to identify common areas of functionality - so that the data can be shared across as many services as possible. The principle of "collect data once, share and use it many times" applies. The logical architecture is independent of any hardware or software approach.

Whilst all ITS Architectures have a logical architecture, the need to make it visible depends on the type of ITS architecture that is being created and how it is to be used. Generally speaking framework ITS Architectures need them, but customised ITS Architectures do not. How the logical architecture - or functional viewpoint - appears and is accessed will depend on which type of ITS architecture is used as the starting point for its creation.

PHYSICAL ARCHITECTURE OR VIEWPOINT

In the context of systems engineering, the physical architecture or viewpoint shows how the functionality defined by the logical architecture (or functional viewpoint) is to be distributed amongst the system components in different organisations and locations. It is not a detailed design, nor does it include details on specific numbers of systems or equipment at particular geographic locations. Responsibility for the ownership, operation and maintenance of the system components may also be divided between different organisations.

One of the advantages of using a framework ITS architecture (such as the European FRAME architecture) is the option of exploring alternative physical architectures whilst maintaining the same logical architecture.

This makes it possible to arrive at an optimal distribution of functionality in response to local requirements.

COMMUNICATIONS ARCHITECTURE OR VIEWPOINT

The communications architecture or viewpoint is created from the physical architecture and provides a more detailed specification of the data flows. It is at this point that the data flow characteristics are defined, such as how long the data transfer can take, how often, what security will be needed and how much data there is likely to be. The need for inter-operability can be assessed - for example enabling the same form of electronic payment to be used for all services. These detailed specifications enable a search to be made for suitable local, national or international communications standards. Existing standards should always be used wherever possible as this avoids the (sometimes lengthy) standards creation process and may make it possible to use existing telecommunications infrastructures. This means ITS deployments can take advantage of the rapid changes taking place in the telecommunications industry. Choice of communications will depend on what is available locally and the tariffs that can be negotiated with service providers. These issues need to be explored with the communications providers.

ORGANISATIONAL ARCHITECTURE OR VIEWPOINT

The organisational architecture or viewpoint is also created from the physical architecture and shows who will be responsible for the operation, maintenance and management of the components and communications links. It will also highlight the organisational structure that will be needed to support the ITS implementation so that it can be compared with what currently exists. This enables any changes that will be needed in organisational structure, roles and responsibilities to be described and then agreed by the stakeholders before the ITS implementation has begun.

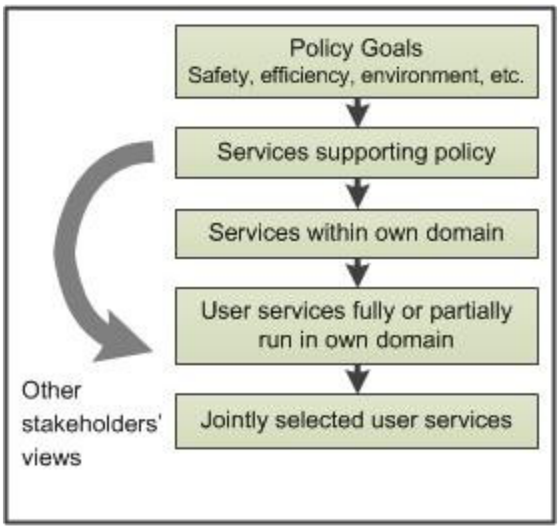
SYSTEM BOUNDARY

This is an important but sometimes overlooked concept that defines the external boundaries of the ITS implementation - and where and in what form, interfaces are needed between the subsystems and the end users. As well as describing the interfaces it is also necessary to describe how the subsystems expect what is outside the ITS implementation to behave. An example of such an interface is the connection to a vehicle registration database held by the police or licensing authority which an ITS subsystem may need to access for the purposes of collecting electronic toll payments. For the ITS architecture the description of the database need only say what it is expected to do, e.g. provide contact information for a specific vehicle identity.

One important point to note is that end users that are human beings, e.g. travellers, system operators, transport planners and fleet managers, are always outside the system boundary. It is the input and output interfaces that are provided for their use that are inside the system boundary.

WHY CREATE AN ITS ARCHITECTURE?

Within any single country or region, there are likely to be large differences between the set of ITS services useful for big cities and for rural areas. Many ITS applications (such as navigation and location based services) are market driven. In road network operations there are always key stakeholder groups, public authorities and private sector organisations with a part to play (for example - in motorway network management, traffic control and toll road operations). Each has different organisational areas of competence or responsibility (such as road safety, public transport, fleet logistics, policing and public security). Each has its own policy goals. Alongside there are the wider community objectives of improving road safety, transport efficiency and environmental quality. The process of stakeholder consultation is intended to take account of the bigger picture – to identify what ITS services are viable and how they should be implemented. This is outlined in the diagram below, which shows that the first step is to define the policy goals, and then identify the services that will support these goals. Stakeholders nominate the ITS services that will run either fully or partially within their own domains. These are then amalgamated to provide a set of services that have been jointly selected by all stakeholders.



Expression of Policy Goals in ITS Service Selection

The process of getting stakeholders involved should start by asking them to describe in their own words the services that they want the ITS deployment to include. In discussion these descriptions can then be modified so that they will support the policy goals. (See later more detailed section on "Describing the Services") It can be very beneficial if this is done through a "stakeholder conference" so that the various groups can meet each other, discuss the options and understand each other's requirements. Often this will lead to the realisation that some of the services can be enhanced by exchanging data or information between different stakeholders.

For example, the highway network operators may be planning to deploy ITS for electronic tolling and automatic incident detection. This functionality can be adapted to give high-quality traffic and traveller information, with point-to-point journey times. An alliance between the network operators, toll road companies and the information service providers is needed to make this happen. The consortium will need to agree joint use of the ITS infrastructure, protocols for information exchange, and the data and information that they will use. All can be included in a common ITS architecture which serves the needs of all the partners.

Another example might involve the motorway network operators considering the use of ramp metering to maintain smooth traffic flow. An undesirable side effect can be long queues of vehicles that spill out onto the surrounding roads causing gridlock. Measures are needed to ensure that this does not happen. There may also be pressure to prioritise buses and coaches and other high-occupancy vehicles waiting on the ramp. The two network operators - for the motorways and the surrounding roads – need to design their traffic management policies and ITS deployments to minimise the conflict. This might involve some form of demand management with measures to encourage modal shift.

These examples emphasise the value of taking a broad view of the ITS deployment rather than each agency or organisation working in isolation. Collaborative working early on - to define the full scope of ITS deployment - means that changes can be made at relatively low cost before systems are designed and equipment has been purchased.

BENEFITS OF CREATING AND USING ITS ARCHITECTURES

The benefits of creating and using ITS architectures depend on the different perspectives that stakeholders have: road network operators, transport service providers, suppliers.

ROAD NETWORK OPERATORS

The beneficiaries of ITS may be road authorities, road operating companies – who can benefit from ITS architectures in various ways:

- through technology independence with easier planning for long term investment and how future upgrades can be made;
- by creating an open market for components, communications and systems from a choice of suppliers based on the use of publicly available standards;
- lower costs through more open competition amongst ITS equipment and service suppliers and communications providers.

TRANSPORT SERVICE PROVIDERS

Organisations that are concerned with the mobility of people and the movement of freight include national and local authorities and fleet operators concerned with intermodal transport – for whom ITS architectures provide the following benefits:

- a planned approach to the deployment of ITS services (such as travel and journey planning, vehicle fleet tracking, load monitoring, or secure parking for trucks);
- the use of compatible equipment with the same components and interfaces being used elsewhere

to benefit from interoperability, data re-use and avoiding redundant investment;
- the potential to integrate one service with another in a seamless and logical way.

SUPPLIERS

Suppliers may be component suppliers, communications providers or system integrators - for whom ITS architecture provides the following benefits:

- lower risk for investments in system, component and communications developments consistent with the common approach provided by the architecture;
- the possibility of larger more profitable production runs arising from the use of "open systems" and publicly available standards - which can enlarge the market place;
- greater opportunities for small and medium enterprises to participate in the supply chain by providing specialised components.

ALL STAKEHOLDERS

An architecture approach can help all stakeholders to:

1. explore alternative system configurations – for example to understand the advantages and disadvantages of processing data in particular physical locations;
2. elaborate what their ITS deployment needs to do in practice - providing a better insight into its contribution to current operations and future plans;
3. refine the specifications and requirements for components and communications before significant investments are made.

RISKS OF NOT USING ITS ARCHITECTURES

The risks of not carrying out the process of developing an ITS architecture may include:

- failure to meet the expectations of stakeholders when the ITS deployment was first considered;
- lack of appreciation of integration opportunities for the ITS services;
- a limited appraisal of design opportunities – for example:
    - dependence on proprietary systems (often specific to one supplier for all components). Whilst proprietary systems may offer benefits in terms of favourable purchase terms – later expansion, maintenance and integration with other services may become difficult;
    - limiting the options to further develop services because of a choice of a particular type and style of telecommunications;
    - technical system choices that may in time become obsolete.

If any of the risks are realised in practice, the costs involved in mitigating or correcting them will be significant. In some instances the only way forward is to "start again", and this time use an ITS architecture.

WORDS OF ENCOURAGEMENT

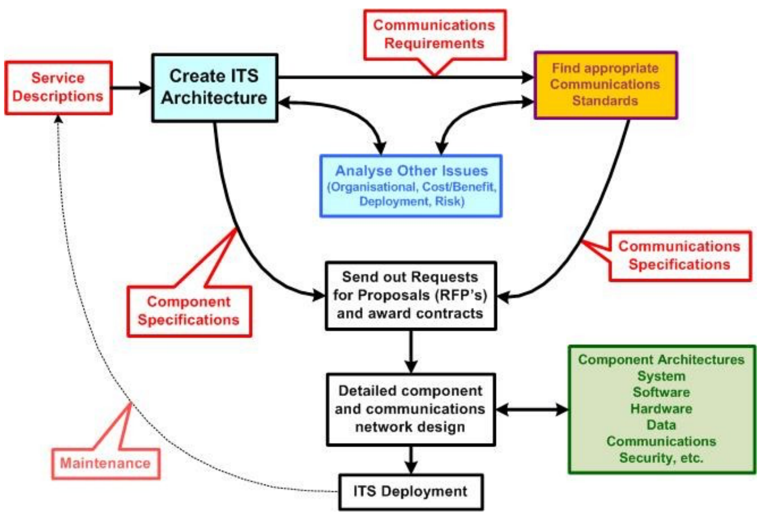
Despite all the benefits just described for developing an ITS Architecture, convincing the people that creating and using ITS architectures is of benefit to ITS implementation is not always easy. There are several reasons for this, the most prominent of which is that ITS architectures are seen as a constraint on commercial suppliers and system integrators. In fact they may be more liberating than a constraint because they enable stakeholders to appreciate how the ITS implementation will appear to them and what it will do for them. ITS architectures also enable stakeholders to consider all the options for the ITS implementation, including choosing to use technologies that are a best match, or if they don't exist, incentivise some research to find them.

The process of creating and using ITS architectures enables stakeholders to be much clearer about the services they want from the proposed ITS deployment – what it will do and what it will look like. As a result there will be fewer "surprises" when the ITS implementation starts up. It will help to avoid negative comments such as "I didn't know it would do that", or "I wish it didn't do that", or "I wish it could ….".

The benefits of creating and using ITS architectures need to be "sold" to the people, who are often referred to as "decision makers", meaning the people who decide that ITS will be implemented and that the finances will be made available to do it. In some instances a few of the stakeholders may also need to be convinced. So it is necessary to have a good "selling" pitch that can be tailored to suit each type of audience.

THE USE OF ITS ARCHITECTURES IN THE ITS IMPLEMENTATION PROCESS

The use of ITS architectures in the ITS implementation process comes before any of the components or communications have been purchased or designed. This is because they do not contain any reference to technologies. In fact the component specifications and communications requirements produced from ITS architectures can be used as input to the procurement process. This is illustrated by the diagram below.

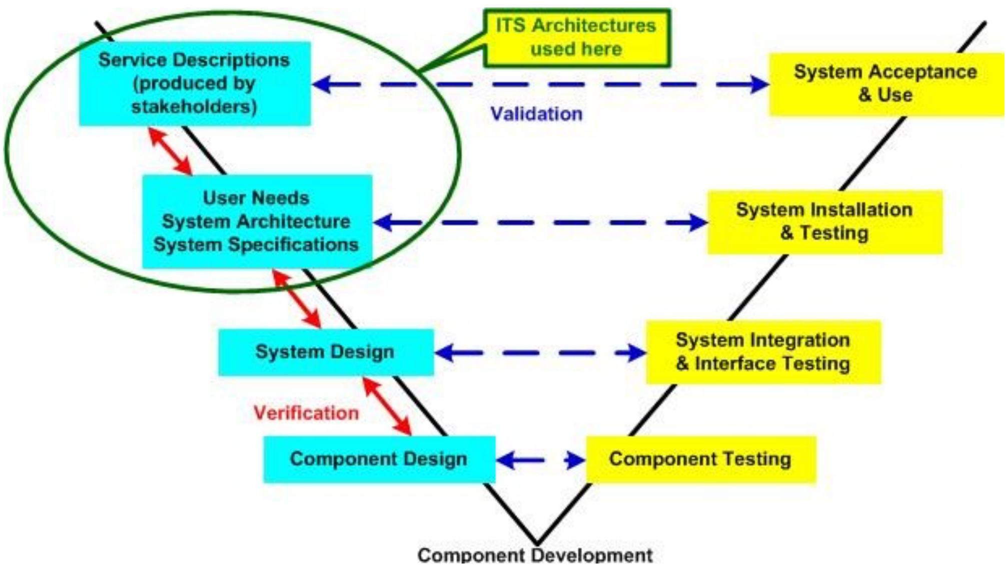


The use of ITS architectures in the ITS implementation process

Organisations use various terms for the procurement process – such as "Requests for Proposals", "Call for Tenders" or "Request for Solicitations". What is important is that the architecture is included in the contract documents and is used by suppliers, communications providers and system integrators when developing their proposals. This ensures that the specification for components and communications will deliver the ITS services described by the stakeholders.

As part of their bid responses - suppliers, communications providers and system integrators can be asked to illustrate their proposals with their own system, software, hardware, data and communications architectures, all of which are low-level or component architectures. Each one can be compared with the ITS architecture to make sure that they conform to requirements and show a good understanding of what the stakeholders want.

ITS architectures are also included in the systems engineering "V" model, as illustrated by the diagram below.



ITS architecture in the Systems Engineering

OTHER ARCHITECTURE METHODOLOGIES

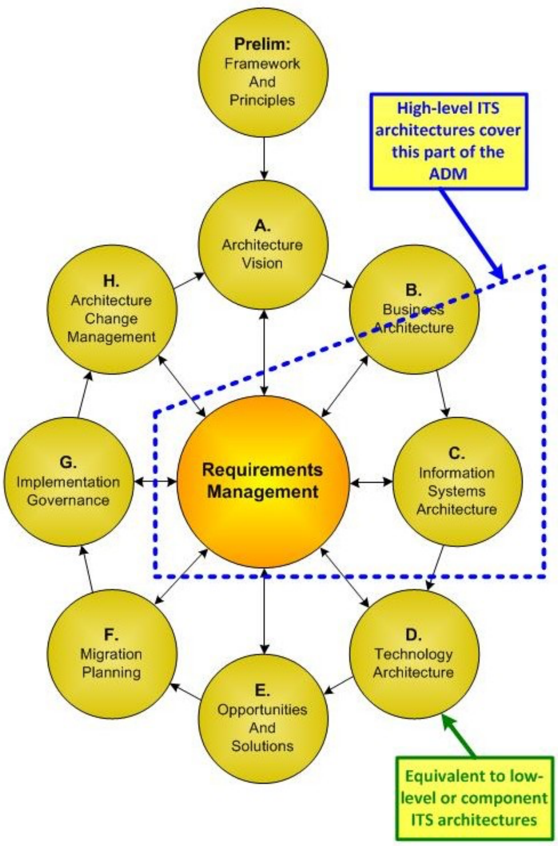
There are a few other architecture methodologies that are in use around the world, which are mentioned here for completeness. Probably the most common of these are Enterprise Architectures, the Open Group Architecture Framework (TOGAF) and Object Orientated/UML Architectures. All three approaches cover more than just the architecture and go into system implementation and maintenance.

ENTERPRISE ARCHITECTURES

An Enterprise Architecture is a well-defined practice that can be used by organisations to guide the development of their businesses. It considers the business to be an "enterprise" and is perhaps the successor to "business architectures" that use business process modelling techniques. The concept of an Enterprise Architecture is attributed to John Zachmann when he worked for IBM in the 1980's and was responsible for the "Zachmann Diagram". It has been developed and updated several times since by organisations such as the Enterprise Architecture Centre of Excellence (EACOE). As far as is known, Enterprise Architectures have never been used for ITS implementations. The creation and use of ITS architectures does fit well with the Zachmann Diagram and is part "Business Model" and "System Model", with the preparation of the service descriptions being part of its "Scope" phase.

THE OPEN GROUP ARCHITECTURE FRAMEWORK (TOGAF)

Another methodology that can be used for ITS implementation is TOGAF (The Open Group Architecture Framework). It is robust and used in many parts of the world, backed by a strong user community that offers professional certification for those that use it (TOGAF practitioners). TOGAF Architecture Development Methodology (ADM) divides architecture creation and use into several phases as shown in the figure below. The phases are similar to the steps shown in the figure on ITS architecture in the Systems Engineering "V" Model.



Relationship between the TOGAF Architecture Development Methodology (ADM) and typical ITS Architectures

Some phases of TOGAF are not covered either by high-level ITS architectures or by low-level ITS component architectures. These additional phases can cover subsequent steps in the ITS implementation process, such as procurement, installation, and operation. Including these steps within the architecture has the advantage of delivering both the actual solution, as well as closing the loop and updating the ITS architecture.

OBJECT ORIENTATED ARCHITECTURES

Object orientated methodology has been long established for software and system design and is almost always illustrated using the Unified Modelling Language (UML). So far as is known only two ITS architectures have adopted it: the ITS architecture developed by ISO TC204 in 1998 and the Australian ITS Architecture, which was developed a few years later. based on ISO.

The ISO ITS architecture has largely remained untouched since it was produced and may now be lacking in support for many of the ITS services used today. The Australian ITS Architecture was also little used. In the last few years, Australia has begun development of a new Australian National ITS Architecture. It is following the route taken by most High-Level ITS Architectures that have been developed around the world and using the methodology described in this module.

It is probably true to say that the object orientated methodology is inappropriate for use by people outside of the IT industry since it requires practice to become familiar with it. This methodology is more appropriate for low level (or component level) ITS architectures that are used by system and software developers.

ISSUES FOR DEVELOPING ECONOMIES

Many developing economies will have little or no experience of ITS. This means that there will be very few existing ITS deployments and where they do exist, they will often be standalone having no links with any other systems. Thus any new ITS implementation will be starting from what is virtually a "greenfield site". In this situation, creating and using ITS architectures is virtually a "must" since it provides the greatest opportunity for assessing all of the options for component and communications configurations. This should be done without the influences of suppliers and providers, who will inevitably be keen to sell their own products, but should take account of what standards are available, particularly for communications.

Creating and using ITS architectures will provide the opportunity to specify components and communications that will produce an ITS implementation that is "open" – one that uses open, or publicly available, standards to which anyone can conform. This will in turn widen the potential supplier and provider base, in other words make it easier for a broader range of companies to tender for the supply of components and the provision of communications. This will apply not only to the initial ITS implementation but also to future expansions and upgrades, thus avoiding the trap of being "locked into" a particular source of components and communications.

HOW TO CREATE AN ITS ARCHITECTURE?

There are two ways to create ITS architectures, either starting from nothing or by modifying an existing ITS architecture. Both approaches are directly related to the type of architecture from which they will be created (which could be either a "model" architecture such as the US National ITS Architecture or a framework architecture such as the European FRAME Architecture).

There has been much experience with ITS research, development and deployment - which is captured in two widely used architectures that exist today. The US and FRAME architectures have evolved with ITS over the past 20 years. Both have been refined to keep pace with ITS development and deployment in the two regions – and domestic and international standards have been developed, based on them. It would be very expensive to approach a new architecture development starting "from nothing". Adapting or adopting ITS functional definition from existing architectures offers a cost effective approach for a new architecture definition provided that the local user needs, institutional set-up and transport context (such as the package of user services, modal choices and traffic mix) are addressed. These may vary considerably from the assumptions inherent in either the US or FRAME Architectures.

The two ways of creating an architecture (start from nothing or adapt an existing architecture) share a common starting point. This is the description of the services that the ITS deployment is to provide - which has to be reflected in the ITS architecture. The process can be summarised as follows:

Service Descriptions -> User Needs -> Functional Definition -> Physical Partitioning -> Communications -> Linkages to Standards.

OPERATIONAL CONCEPTS /OPERATIONAL REQUIREMENTS

In the process shown above, any detailed concepts about how the services are to be delivered will be part of the "User Needs". They are often referred to as "operational concepts" and "operational requirements" and are constraints that need to be applied in the ITS implementation process following the creation of the ITS architecture. Examples are a service "must be available all day every day (i.e. 24/7)", or a service "must be available in the same way everywhere". To highlight their importance these concepts are best captured in a Concept of Operations (ConOps) document that contains descriptions of how the services will actually work. To do this, the document requires inputs from some of the architecture viewpoints created later on in the ITS architecture creation process. So whilst creation of the ConOps document may be started early on in this process, it cannot be completed until nearer its end.

DESCRIBING THE SERVICES

Describing the services that the ITS implementation is to provide is the first and most important step in the creation of ITS architectures. It is the foundation for all subsequent architecture development activities.

CONSULTATION WITH STAKEHOLDERS

Generating the description of each service is best started by having a dialogue between the architecture team and those who want the service provided – usually referred to as stakeholders and who may be any of the following:

- those responsible for traffic management and road network operations
- those who "use" ITS services such as travellers and organisations that move people and goods as part of their businesses
- government departments and agencies for whom ITS services can be a means of implementing government transport, social (accessibility and inclusivity) or environmental policies
- organisations for whom the provision of a new ITS related travel service is a way of enhancing and expanding their businesses
- manufacturers of ITS components, who want to broaden their product range and see an opportunity to do this through providing new vehicle or mobility related services

The process of engaging with stakeholders involves a sequence of activities:

- Initial Outreach: to raise awareness of the project and identify the stakeholder community
- Meetings: with the stakeholders to understand their requirements and where possible develop consensus on operational needs and supporting ITS deployments, producing what are called stakeholder aspirations
- Ongoing Dialogue: to support architecture development and review project deliverables

The development team will need to meet key stakeholders, either individually, or as a group such as "road users", or a "quality circle."

Another group to be consulted with be policy makers so that the services the ITS architecture provides will support national and regional policies. If a "vision" statement for the ITS implementation has been produced – those who developed it will need to be consulted. Another alternative is to select stakeholders by what they do (their function) – such as:

- police, emergency services and road operators who are all involved in responses to incidents
- port authorities, goods transport operators and road operators who are all involved in managing the movement of goods to and from ports
- a relevant group of commercial businesses – for example toll road operators, information service providers or car park operators

At these meetings just asking the attendees what ITS services they would like to see may not produce any real detail on the services the stakeholders want, from which the stakeholder aspirations can be produced. Often more will be achieved by discussing what each stakeholder does, any problems they currently have (for example delivering policy outcomes or developing user services) and how they see their activities will develop in the future. A useful question to ask is "what will be the organisation's main activities in 3-5 years' time?" This type of question will focus discussion on what ITS features or facilities are desirable in the future.

The architecture team will need to be represented by at least 2 people - one to lead the discussion and the other to take notes. Each meeting should be planned to last long enough to explore the issues in depth (often between half a day and a whole day depending on the number of attendees). How many meetings will be needed depends on the number of stakeholders and whether the team meets them individually or in groups. The advantages of either option are:

- meeting individually – provides an opportunity for frank and open discussion which may touch on matters of a sensitive nature
- meeting in groups - is an opportunity for interaction between stakeholders and for developing a common understanding of what the ITS deployment is about – to reach agreement on its scope and essential requirements – and each party’s roles and responsibilities

When all the meetings have been completed the architecture team will need to produce a report that describes each of the services the stakeholders want (*Service Descriptions*) included in the ITS implementation. The end result must be an agreed set of service descriptions that the stakeholders are prepared to endorse through their commitment to supporting the ITS implementation.

"START FROM NOTHING"

This approach creates the ITS architecture as something new, starting only from the service descriptions produced in conjunction with the stakeholders. This approach is not recommended for the following reasons:

- based on experience with other ITS architectures, considerable resources will be needed, such as 3 person years of effort spread over a 2 year period
- the ITS architecture may not be compatible with other ITS architectures currently known to be in use around the world
- although the ITS architecture can be created with "standard" tools such as Microsoft WORD, VISIO and Access, it will be difficult to properly check it for consistency, so a specialist tool will be needed at extra cost
- experience from many other ITS architectures has shown that the Process Oriented Methodology is best suited to ITS architectures (see ISO TR26999) - which may require some training for those involved to become familiar with its way of working, though its rules are "obvious"

There are a few specialist software tools available for ITS architecture creation. The two most widely used are probably System Architect from IBM and the Mega Process business modelling tool from Mega International.

ADAPT AN EXISTING ITS ARCHITECTURE

Starting from an existing ITS architecture is normally the best way to create a new ITS architectures It builds on the experience gained from the creation of the existing ITS architecture – with the benefit of assistance being available from one or more sources if needed. There are two widely used options for creating ITS architectures in this way:

- use the US National ITS Architecture, which is a "model" architecture

- use the European ITS Framework Architecture (often known as the "FRAME Architecture")

An ITS architecture that has been developed for one set of circumstances can be adapted and used as a starting point for other ITS architectures elsewhere if the circumstances are similar. For example an ITS Architecture created for one region might be successfully adapted to another region with suitable modifications. In general the ITS architecture development process follows the sequence:

Service Descriptions -> User Needs -> Functional Definition -> Physical Partitioning -> Communications -> Linkages to Standards.

The “operational concepts” and “operational requirements” explained above should be included in the user needs and will be important in the later steps in the ITS implementation process. They should also be covered by the Operations document.

The above process applies to any the creation of any ITS architecture. FRAME and the US Architecture both provide inputs to each of these process steps in different ways. Where the starting point is the:

- US National ITS Architecture – its Turbo Architecture tool can be used to create variants of ITS architecture. There are 300 examples of its use as a starting point for customising ITS architectures
- European FRAME Architecture - its Selection Tool enables a single set of functionality (called a functional viewpoint) to be created from the FRAME **User Needs Descriptions**. From this selection of one or more physical viewpoints can be created containing the same functionality but possibly in different physical locations

ADVICE TO PRACTITIONERS

Before a choice can be made between the two starting points, it is important to have discussed and answered the following questions:

- has the scope of the ITS implementation been discussed with the main stakeholders? As a minimum, the outlines of the service descriptions should be created to clarify what the stakeholders are expecting to be delivered
- has it been decided how the ITS architecture will be used? For example is it for a one-off ITS implementation and if so - is it likely that it will be expanded in the future - either by adding new services or expanding the geographic coverage?
- is it going to be an ITS architecture from which other ITS architectures will be created, and if so how much control is to be exercised over the customised ITS architectures that are derived?

The answers to these questions will help to decide which method is to be used to create the ITS architecture. Whatever the answers, use caution if the "Start From Nothing" approach is used because it will require a heavy commitment of resources over a long period of time without the benefit provided by an existing ITS community.

Choosing between the two options to “Adapt an existing ITS architecture” is a balance between the following issues:

- US Architecture – easy to use as a “model” architecture requiring little or no knowledge of the technical detail behind the ITS architecture creation process; but adapting it to incorporate local variations and/or completely new ITS services is not something that many users can do easily

- FRAME Architecture – requires a more intimate knowledge of the technical aspects of how to create an ITS architecture, but is very flexible and can be adapted to include local variations or new services if users follow the detailed guidance that is provided

If the services described by the stakeholders have a "US flavour" then the US National ITS Architecture is the obvious starting point – particularly if it is used for a single ITS implementation. In this case it is only the content of the services that is the deciding factor.

If there is not a good match between the services selected by the stakeholders and the US User Services or Service Packages, then the FRAME Architecture is a better starting point as it will be easier to adapt.

ISSUES FOR DEVELOPING ECONOMIES

Developing economies may have little or no existing ITS components or communications. This means that the ITS architecture will be describing what can be viewed as a "greenfield" ITS implementation. It is tempting to think that the best way forward is to adopt the "From Nothing" approach. This is not necessarily true for reasons of cost, complexity and the lack of support from an existing ITS architecture user community.

RESOURCES

Before starting work on creating the ITS architecture it is very important to estimate the resources that will be needed. The best way to do this is to split the work of creating the ITS architecture into three phases:

- **Phase 1** – creating the service descriptions
- **Phase 2** – creating the ITS architecture
- **Phase 3** – carrying out the follow-on activities

The numbers of people needed for each phase will depend on the number of stakeholders and the expected scope of the services that the ITS implementation is to provide.

PHASE 1 – CREATING THE SERVICE DESCRIPTIONS

Experience has shown that it is impractical to have only one person at the meetings with stakeholders to enable the Stakeholder Aspirations to be captured. This is because it is virtually impossible to direct the course of a meeting and take meaningful notes of what is said at the same time. Stakeholders can be encouraged to submit written descriptions of the ITS services they need or aspire to (“*Stakeholder Aspirations*”), but holding stakeholder meetings, either individually or in groups is a better way to gather this type of information. An accurate record of what is said at these meetings will be an invaluable aid to developing the detailed *Service Descriptions*. Discussions with stakeholders before the architecture is developed are likely to produce *“Stakeholder Aspirations”* rather than strict, specific *Service Descriptions* which need to be refined by the Architecture Team before starting work on creating the ITS architecture.

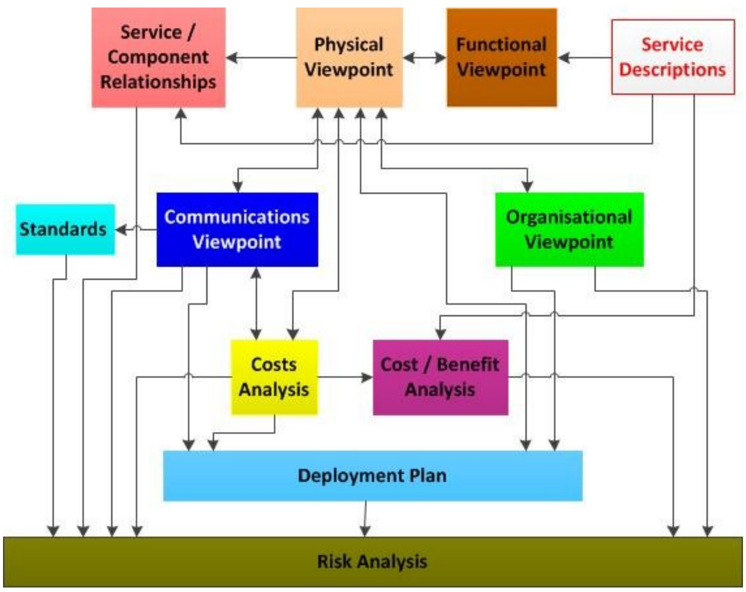
At least two people will be needed for each stakeholder meeting – one to lead the discussion and the other to take notes. If a large number of stakeholder meetings are needed, it may be necessary to deploy teams of two people each, so that meetings between non-related groups of stakeholders can be held in parallel. For most ITS implementations, the time taken to produce the service descriptions to the level of detail required, will be about 6 months, since it is usually necessary to talk to stakeholder representatives whose diaries are often very full.

PHASE 2 – CREATING THE ITS ARCHITECTURE

Previous experience suggests that having more than one person working on the actual creation of the ITS architecture does not save time or effort and may produce inconsistencies within it. The best solution is to have one person creating the architecture and at least one person to review it.
If the ITS architecture is be created from either the US National ITS Architecture or the European FRAME Architecture, then the time required should be relatively short - about one month should be sufficient and includes the creation of the physical viewpoint. If the "Start from Nothing" approach is taken, then the time taken will be considerably longer – probably about 9 months for a small scale ITS project and up to 2 years for a more extensive architecture.

PHASE 3 – CARRYING OUT THE FOLLOW-ON ACTIVITIES

Creating the different viewpoints for an ITS architecture (physical, communications, organisational) and analysing other aspects of the ITS implementation (deployment, cost-benefit, risk analysis) can be undertaken by several people – if necessary working in parallel. The possibilities for parallel working can best be seen from the diagram below.



Relationships between different ITS architecture viewpoints and other aspects of ITS implementation

Many of the links are bi-directional because work on one view or viewpoint can affect the contents of a previously created view or viewpoint. So for example, physical and communications constraints identified by work on their viewpoints can require changes to the way that the functionality is partitioned in the functional viewpoint.

It is tempting to think that some ITS architectures will not need all of these viewpoints or an analysis of the other aspects, for example when the ITS architecture for a research and development project. In practice this is not true. What will vary is the level of detail that is needed, so that for example, an ITS architecture for a single service may require less detail in its organisational viewpoint, plus a much simpler treatment of deployment, cost/benefit and risk.

To create all of these viewpoints and other outputs three people will be needed and they should be able to complete the work in three months. Obviously if less detail is required then the amount of effort reduces, which can be expressed either as a reduction in people or in the time taken.

Overall estimate of resources required to create an ITS architecture

The following table summarises the three phases of ITS architecture creation.

	Phase	Number of people	Duration (months)	
Number	Title	Minimum	Ideal	
1	Creating the service descriptions	2	up to 4	up to 6
2	Creating the ITS architecture	1	up to 3	1
3	Carrying out the follow-on activities	2	up to 3	up to 3

The conclusion from the table is that between 2 and 4 people will be needed for a period of up to 10 months. It is advisable for each team member to work on the three phases of architecture development rather than focusing just on one.

RESOURCES NEEDED TO MAINTAIN AN ITS ARCHITECTURE

Once the ITS architecture has been created, it needs to be maintained and kept relevant if it is to continue to serve a useful purpose. The resources required to do this should be small, with two people needed for a period of about 6 months every 12-18 months – but this will depend on the size of the project. The need to update the ITS architecture will depend on the speed of the evolution of ITS and the stakeholders' need for implementing new ITS applications.

ADVICE TO PRACTITIONERS

When allocating resources, it is helpful to keep in mind the long term situation and the need to keep the ITS architecture consistent with the continual evolution of ITS. For large ITS architectures, such as those with several different types of service (for example, traffic management, public transport and tolling) it will be cost effective to employ the same person to create and maintain the architecture. The dividends will be reduced staff resource time because of retained knowledge, which in turn can be translated into reduced costs. Stakeholders will be dealing with someone who knows about the ITS architecture, which will inspire them with confidence.

ISSUES FOR DEVELOPING ECONOMIES

It is possible that there will be no suitable local expertise to create the architecture but dependency on the use of consultants will be expensive. A better plan may be to train at least two locally-based people to create the ITS architecture and carry out the maintenance work – drawing on a mentor for help and advice. The locally based people do not have to be software or hardware engineers - in fact it is probably better if they are not. Computer literacy, willingness to learn and enthusiasm are the prime requirements, with some knowledge of ITS being a great help. Local staff will be better placed to appreciate what the stakeholders want from ITS.

USING ITS ARCHITECTURE

What happens after the ITS architecture has been created depends on the type of architecture and the starting point used for its creation. The possibilities can be reduced to:

- develop further analysis for the ITS implementation (some are called viewpoints)
- use the Architecture as the starting point for the creation of sub-set ITS architectures

Model architectures which have been customised can be used to develop other viewpoints (such as the organisational viewpoint) but may be more difficult to use as the starting point for the development of a new sub-set of architectures. Framework architectures can be easier to use to explore different physical and/or communications viewpoints and to create new sub-sets to support new separate services, or combinations of services.

EXPLORING DIFFERENT ITS CONFIGURATIONS

Sometimes it can be helpful to study the impact of different physical and communications viewpoints on the ITS implementation. It can be useful to create different physical viewpoints with alternative component configurations and look at the effects the alternatives have on the communications and organisational viewpoints, and other important aspects of deployment such as cost/benefit. This process can help identify the optimum system configuration that:

- puts the components in the physical locations that make them easier to deploy
- uses the most appropriate communications networks
- has an acceptable deployment and/or operation cost
- whilst still providing the desired services

Each implementation configuration is analysed using the architectural tools for the US ITS Architecture or FRAME (as appropriate) and the results from creating the ITS architecture in the following ways:

- physical viewpoint – this shows where each component will be physically located and the functionality it will contain. This is one of the outputs provided by the US Turbo Architecture and the FRAME Selection Tools and it can be useful to study alternative ways of distributing the functionality between components. The downside of this study is that it can hinder the development of "standard" components.
- communications viewpoint – this contains the requirements for each link that enables the components to exchange data with each other and with the outside world. It is created from the physical viewpoint using estimates of the data in each link and any other performance characteristics – such as communication latency (delay). An example of the detail required is shown in the Communications Viewpoint for Kent County Council.
- standards – as the communications viewpoint table is created for each link, it can be used to determine

the standards that they will each need to use. The US National ITS Architecture has been developed to provide the links from information flows to specific ITS or industry standards. In the Kent example, the options for fixed line communications standards will need to be identified and the most appropriate selected. Other communication links may involve standards such as those between moving objects (vehicle to vehicle communications) or between moving and stationary objects (vehicle to infrastructure communications). In some instances standards may also have to be applied to the components to cover a diversity of things such as appearance, location, use interface, tolerance of environmental conditions, maintenance, power source and durability.

- organisational viewpoint – this is used to show the organisational structure that will be needed to manage and operate the components and communications links. If the FRAME Architecture was used as the starting point, this viewpoint can be created using the FRAME Selection Tool. It is used to identify the impacts on and changes needed to the existing organisational structure.
- system boundary – this is used to define what is part of the ITS implementation and what is outside it. People are outside and communicate through a component that provides a human machine interface (HMI). Other non-ITS systems, such as those for financial transactions are outside. The system boundary can be shown in what is called a "context diagram". An example is provided for Kent.
- deployment plan – this is produced from the physical and communications viewpoints to show the order in which components and communications links can be deployed and how those that already exist can be re-used or replaced. It may require a survey to find out if any ITS related equipment is currently in use so that an assessment can be made of its value for the implementation described by the ITS architecture.
- costs analysis – a rough estimate of the capital and revenue costs (often based on previous experience) can be produced using the component descriptions and communications requirements. Using the deployment plan a cost profile can be produced to show when the costs will be incurred as the ITS implementation progresses.
- cost/benefit analysis – this analysis may be more difficult to perform as estimating the benefits is not always easy. Help can be sought from organisations such as the International Benefit, Evaluation and Costs (IBEC) Working Group. The cost/benefit ratios that are produced will need to be benchmarked against other similar ITS implementations.
- risk analysis – identifying the areas of risk that may be attached to deploying the components and communications links is very useful, as well as looking at other issues such as impacts on existing organisations, the availability of suitable technologies, problems with user acceptance. It should include consideration of the organisation(s) responsible for the mitigation of any identified risks.
- Service descriptions/component relationships – developing these can be very useful when proceeding from architecture development to deployment as it shows the component(s) that are involved in the provision of each service. With the US Architecture services and the components or subsystems associated with each service are accessible and can be edited using the Turbo Architecture. For the FRAME architecture the service relationships can be created directly from the database used by the FRAME Selection Tool as shown in the table for ITS sub-systems in the Kent example.

As can be seen from the diagram, some of the relationships are two-way and the architecture may need revising to create the optimal system configuration as a result of analysing different aspects of the planned implementation. One of the benefits of creating an ITS architecture is being able to do this at an early stage before any contracts have been placed for equipment and communications to be designed and/or purchased.

CONCEPT OF OPERATIONS DOCUMENT

For some ITS architecture practitioners the creation of a Concept of Operations (or ConOps) document is a key part of the ITS architecture creation process. Its usefulness depends on how the ITS architecture is going to be used and the content of both the functional and physical viewpoints.

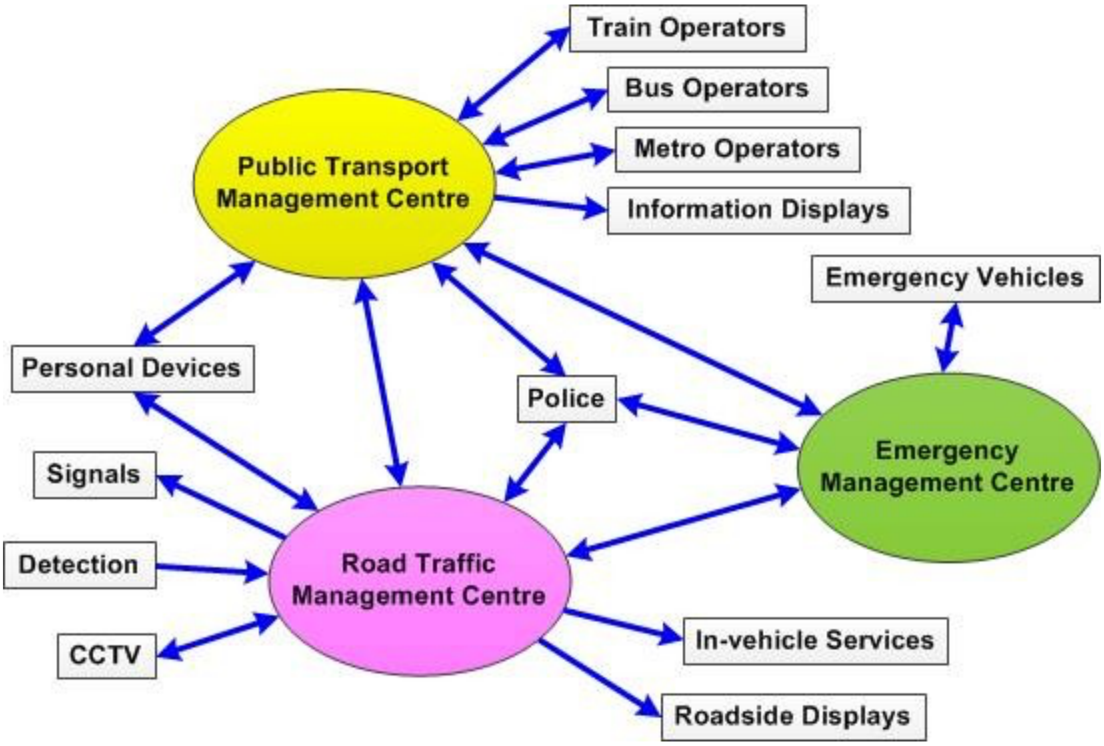
The ConOps document can be used to provide answers to stakeholders' questions about what is needed, how it works, who is involved and when it is needed. In order to produce this document, the starting point must be the service descriptions produced at the start of the ITS creation process. And it is for this reason that some ITS architecture practitioners believe it should be produced before the viewpoints and views are created. Indeed it can be used as a mechanism for creating the initial view of the functionality before it is put into the functional viewpoint. However if this is done, the ConOps document should only be regarded as "work in progress" and not considered "final" until the other viewpoints and views have been produced.

Once the service descriptions have been produced and included in the ConOps document, it can be used to provide answers to the following questions:

- **What**: data/information is to be input/output and how is it obtained/provided
- **How**: the way that the inputs are processed to produce the outputs
- Who: the different levels and areas of responsibility of all those involved in delivering the services
- **When**: what will the end users get, where and when

The information used to answer these questions will be included in the functional, physical, communications and organisational viewpoints. As already noted, this information can be written into the ConOps document as these viewpoints are produced, so long as it is updated after they have been finalised. Alternatively the ConOps document can be produced towards the end of the ITS architecture creation process.

The ConOps document can provide a joined up view of how the services will operate that is not directly provided by the other results of ITS architecture creation. It can also include a diagram to illustrate at a high-level the way that the main components and entities outside the ITS architecture will interact. In practice this diagram will be a combination of the context diagram showing the system boundary and the top level physical viewpoint diagram and could be as shown below.



A typical high-level architectural sketch for Road Network Operations

Like the ITS architecture itself, the ConOps document must not include references to any technology that could be used, or that will need to be developed for the implementation of the service(s) it describes. This is because one of the users of the document will be the stakeholders for whom it can provide a view of how the people creating the ITS architecture believe the service will work. Thus it will be important to get the stakeholders to agree the content of the ConOps document before proceeding to the "Procurement" stage.

Once the stakeholders are happy with the ConOps document its other group of users is the component developers and communications providers. For them it provides the joined up view of how services are to be provided. Therefore and the inclusion in it of any suggestion about technologies to be used will act as a constraint on their design work.

LEGACY/OBSOLESCENCE/UPGRADE

An issue often raised when planning ITS implementations, is how to deal with pre-existing investment in ITS components and communications. The ITS deployment plan produced from the ITS architecture will need to show how these legacy systems are incorporated.

The architecture will inform an analysis of the suitability of any existing ITS components and communications under the following three headings:

- **retain** – this applies to any existing ITS components and/or communications networks that are in the "legacy" phase of their existence but can be retained to form part of the ITS implementation
- **replace** – this applies to any existing ITS components and/or communications networks that have reached "obsolescence" (in other words they cannot be integrated with anything new, modified or

maintained) so they will be replaced with something new in the ITS implementation

- **modify** – this applies to any ITS existing components and/or communications networks that are suitable for an "upgrade" and means that when any necessary modifications have been completed, they will form part of the ITS implementation

In order for these categories to be applied an audit review (inventory and performance appraisal) of existing ITS related components and communications will need to be completed. This is a useful exercise in itself, since it may reveal equipment/installations of which people were unaware or which are at unforeseen locations. An audit of this type is not part of the ITS architecture creation process but is an important part of major new ITS deployments – and can be carried out by people outside the architecture team.

ARCHITECTURE MAINTENANCE

ITS is continually evolving as the travel needs of people, organisations that move goods and other travel related organisations continue to develop. Maintenance is important for the ITS architecture to remain relevant - but often overlooked as there is little enthusiasm to allocate the funds to do it. Some form of a maintenance plan needs to be put in place with an appropriate budget. The size of this budget will depend to some extent upon the number, scope and complexity of the ITS services that the architecture includes. But a very rough guide for budget forecasting purposed is that it should be 10% of the total development cost.

THE MAINTENANCE PLAN

The maintenance plan does not need to be onerous, but it should enable a review of the ITS architecture to be made about once every 12-18 months - or less frequently if the architecture has already been adapted to reflect significant changes to the ITS services. The purpose of the review is to see if any new services need be added to the ITS architecture and deployment plans. This requires discussion about the services currently provided and whether stakeholders want them to be revised, upgraded, or new services added (taking account of the features and performance of services provided elsewhere).

If changes need to be made to the ITS architecture, the maintenance plan should provide for its update, following the same sequence of steps as when a new architecture is created.