Intelligent Transport System (ITS) Capacity Building

Technical Note

2022

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Contents

1 Development of an ITS Masterplan

A masterplan is a dynamic long-term planning document that provides a conceptual layout to guide future growth and development. Developing a masterplan is about making the connection between existing conditions, infrastructure, social requirements, their environments, and where the areas wish to be. A masterplan could include analysis, recommendations, and proposals for an areas' population, economy, housing, transportation, community facilities, and land use. It is based on public input, surveys, planning initiatives, existing development, physical characteristics, and social and economic conditions. Such initiatives are generally long-term propositions, and it is important to consider the master plan as a dynamic document that can be altered based on changing project conditions over time.

Masterplans can have an important role in determining the shape of the urban environment. This document outlines the process that should be considered for the development of an ITS masterplan for an area expecting and planning for growth of itself and the transportation systems.

1.1 Context within a transport (or wider) masterplan

1.1.1 Masterplan Purpose

Initially, it is important to first establish the purpose of producing a masterplan. This could be considered a misleadingly simple question. However, it is important at the start of the process to establish the exact reason for creating the masterplan document. Not conducting thorough reasoning when considering the purpose of the document may lead to risk of time-consuming changes later in the production or following action process. Not correctly understanding the masterplan's purpose may lead to the document not aligning with a 'bigger picture' of efforts for this and other masterplans. Such failures could result in wasted resources, duplicated work, or misaligned and unachievable targets.

To define the purpose of the masterplan, begin by developing understanding about the desires possessed by the parties/governing organisations who commissioned the masterplan. This can define why the area needs a masterplan in the first place and could be centred around shortcomings and issues previously highlighted for address. This allows the outlining of criteria for the developments and in-turn the masterplan's purpose can be established within these criteria. The criteria may include loose goals of improvement within the area for consideration and for how it relates to any neighbouring areas. In this way the areas that require development are defined ready to be built upon later, throughout the masterplan.

1.1.2 Context within the wider Transport masterplan

After defining the purpose of writing the masterplan, the next step is to establish context of where the masterplan sits regarding other masterplan documents. These documents may encompass other masterplans that may consider the same area or similar developments that your masterplan is focusing on. As such it is important to look at any other applicable masterplans as they may add further context to the document being developed.

For example, when developing an ITS masterplan for a defined region, there may be broader transport masterplans for areas encompassing the region of consideration. These documents must be considered as their suggested outputs may not be mutually exclusive with the document being written. This may mean there are existing developmental commitments and

standards that need to be adhered to. Later when aligning strategies with other pre-existing conditions and suggesting interventions to achieve the objectives for the region, the schemes selected may offer enhancement to existing planned/enacted interventions. For example, investing in improving public bus services within the region could be enhanced via ITS technology implementations such as electronic message signs for increased information dissemination.

The ITS masterplan must interpret the transport masterplan, allowing definition of the wider goals that feed the ITS masterplan and fulfil pre-existing regional aims to not forgo prior plans. Similarly, there may be prior iterations of an ITS masterplan. Reviewing these documents to note if the goals have shifted or been fulfilled may help to avoid missing existing issues and avoid duplication of work.

There may also be issues specific to the region that are relevant to the ITS masterplan. It is important to decide if they should be addressed in the masterplan being written, and if so, where they slot in. Alternatively, the issues could be deemed to fall under the wider transport masterplan. By fulfilling the process of investigating the context of the masterplan further, the criteria can be refined. This provides information on how large the freedom of choice will be for the ITS masterplan that you have to deliver, since other masterplans and initiatives for the region may potentially bring restriction.

1.1.3   Define area considered in the masterplan

To understand the constraining factors on the masterplan you are writing, the area you are concerned with must be defined. It is likely that this region may have sub-regions that need unique consideration when compared to an area as a whole (imagine the difference between writing a masterplan for a region over an entire country). Analysing the area should reveal what other developments are being planned or currently taking place within the masterplan area and any surrounding areas. Questions can then be raised as to whether these projects can be developed further and learnt from when considering their outputs. This means the objectives that will be included in the masterplan can be further refined.

1.1.4   Specifying/parametrising elements of the transport system that concern the masterplan

With the purpose of the masterplan and its context amongst other masterplans and the area's developmental agenda defined, the next step is to consider which systems the masterplan will focus on developing, specifically, which transport systems.

An overarching transport masterplan will likely cover many different aspects such as railways and highways. Therefore, the exact transport systems need to be specified here as parameters to allow proper consideration within the whole transport masterplan of what areas the ITS masterplan document should cover. For an ITS masterplan the systems will commonly be related to highways to improve network utilisation by reducing congestion through implementation of strategies that employ various ITS technologies. After covering the sections/systems the ITS masterplan will be looking at, the document can return to understanding the big picture, from an overarching perspective of fulfilling the larger area goals.

1.2   Alignment with other strategies

The previous section focused on context surrounding the masterplan and establishing its purpose. This was built upon to give focus on what systems the masterplan will look at developing. Having considered the surrounding 'big-picture', the masterplan can now further narrow down what issues this masterplan will attempt to tackle.

To achieve the masterplan's purpose, it is important to establish a common vision for developments in the region so that future developments can be coordinated. For example, how do the highlighted issues, or areas earmarked for improvements, align with that of higher echelons. Other masterplans/ developmental agendas for surrounding and overarching areas should have been examined to determine this. Similarly, broader masterplans may have set out overarching goals. The masterplan needs to align with the strategies in these other literature examples, by considering factors such as should improvements be made in conjunction with other improvements to the transport network such as expansions of motorways and other major civil works? Aligning with these strategies may enhance these schemes and offer better benefits for the investment.

Although specific standards and broad strategies may already be in place, there may be goals within the region that are more specific to the masterplan and thus, these will offer greater degrees of freedom when making guidance for interventions.

1.3   Objective and requirement definition

The next section of the masterplan should refine the overall developmental needs into specific system requirements. Firstly, the objectives for the area should be defined. These will be what the masterplan will suggest interventions to solve. The objectives are set broadly and are based upon the areas of the area highlighted in the previous sections, that require development. Considering from the point of view of the whole region, what is the intended goal of making improvements to the road network? These are high-level objectives and so there is no specification of how they will be achieved.

For example, within the area, congestion at peak hours on specific routes could be highlighted as an issue that needs addressing. The object could therefore be set as reduce road traffic congestion at peak hours.

For these objectives, intended quantitative outcomes can be established which allow future interventions performance to be measured. These metrics are selected so that meeting them would be reflected in the region achieving the objectives derived from the purpose of the masterplan and the issues it will attempt tackle.

Continuing with the example, in order to meet the objective, performance outcome should be selected to indicate achievement of the goal. In this case, reduction in journey time by an achievable percent and increased percentage uptake of public transport by the population.

With the objectives and performance outcomes in mind, the masterplan should then advise key requirements that may need to be met to achieve these goals. These are qualitive points and offer no specific metric to measure against or any detail on their implementation. Moreover, they may be focussed on the region only broadly. As such they will not highlight specific schemes or offer starting points for plans of intervention.

Concluding the example, to meet the objective and outcomes, reduction in use of private vehicles, improved public transport links, improved information dissemination for public transport services, and improved network throughput through more efficient utilisation could be some key requirements to include in a masterplan.

1.4   Baseline review (existing equipment review)

The purpose of including a baseline review within the masterplan document is to give the reader an understanding of the hierarchy of the existing transport system and any ITS components that

are already in place. It is important to document in the masterplan whether the region even has ITS technology and how the system is structured.

This answers questions that could be posed such as:

● Does the region have roadside CCTV cameras?
● Are adaptive signalling control systems in place and if so, where?
● Does the area have any enforced low emission zones?

1.4.1 ITS and supporting equipment

Reviewing the existing and supporting equipment allows existing equipment to be incorporated into new strategies/schemes which may help to reduce costs of new interventions and avoid duplication/waste of resources. It may be the case that there are already systems in place that attempt to tackle the issues highlighted in the masterplan. If that is the case, the equipment review can establish what is the output capability of the existing system. If an existing system was deemed to be performing well it could be incorporated into future schemes. Ideally this analysis could be facilitated by up-to-date information that should be held about all current operational equipment within the region. Such information should contain the condition and location of all existing ITS network infrastructure in the region. In addition, it is important to understand how existing equipment on the network interfaces with a management control system or similar, if one is in place. Conversely, it may be determined that systems are not operating in the best possible way and as such are not giving the functional output required. The masterplan needs to answer how all this fits into the system as a whole and what are the limitations of the equipment. This means that decisions can be more easily made about replacing/modifying or leaving the equipment as is. However, keeping an existing system operational would impose a constraint on the masterplan, which takes effect on the guidance and proposals given going forward in the document.

1.4.2 Supporting data (e.g., traffic counts/models/etc.)

Supporting data is used in the masterplan to give an overview of the transport system and shows, at present, what is happening within the transport network. However, since the system is a sum of its parts, it is important to know/predict the possible impact of any changes that could be suggested within the masterplan. This can prevent funds being mis-spent on installing systems that will not correctly address the underlying cause of the issues presented as objectives in the masterplan.

Initially the masterplan should assess what information/data is required and if it is already available through existing infrastructure. For example, traffic count data on links within the region may already be collected routinely by detectors. However, in cases where this information is not available it may be necessary to invest in conducting a data collection survey. This could be fulfilled internally or by outsourcing to a private contractor.

Analysing supporting data means the root causes of the issues initially highlighted in the masterplan can be addressed. Comprehensive analysis of the data will help to increase the likelihood that the underlying causes of the problems are found, preventing falling foul of common statistical fallacies such as data cherry picking, whereby data is selected to fit an existing claim, or in this case expected cause of an issue in the region. Supporting data will also enable further understanding of the issues the masterplan aims to tackle, for example, determining whether the situation is worsening and what kind of change is required to get to the desired position. This will shape selection of future interventions by allowing planners to ensure that proposed solutions are aligned with what is actually required, from looking at quantitative

data. Without using data, it would be difficult to ensure that the masterplan's guidance would have the desired effect on the region.

1.5   Local and strategic interventions

This section of the masterplan should focus on defining interventions to target achieving the desired outcomes. The interventions offer guidance to planners of possible schemes/strategies that could be employed, suggesting the potential output they may bring and discussion of the benefits to the region versus the associated cost (BCR). Later in the masterplan a preferred list of these interventions can be made with explanation for reasons to prioritise investment to these areas.

There are two types of intervention that can be defined called strategic and local interventions. Strategic interventions consist of a large overarching objective, which seeks to fulfil area goals that affects a large portion of the network. These objectives would be achieved using a more comprehensive scheme across the area. Alternatively, local interventions are schemes that are directed actions towards a single point. Thus, the scope of the developments may be lower, or just tackle an issue that does not require as widespread action to tackle it.

This section of the masterplan document should contain information about possible interventions that could be made, relevant to achieving the outputs for the objectives defined in section 1.3. The different interventions may directly reference/enact the key requirements for each objective. For each, the relevant issues the strategy is aimed at alleviating should be explained each time to show the negative impacts on the network and the effects they bring. For each intervention the method in which the different strategies could be implemented should be explained. Importantly, the specifics relative to the actual implementation would not be mentioned. Instead, common characteristics could be discussed to provide an overview of what implementing the strategy would entail, such as the solutions/technologies/systems required to facilitate this and what the intended outputs would be in a generalised approach. Examples could be referenced of where similar schemes have been implemented to help readers when considering investment in the option. The different technologies mentioned should be referenced to an annex section of the masterplan, where more detail is given on the function and utilisation of the technologies from a technical perspective. The expected relative impact of the strategy should also be described to help identify the Benefit-to-Cost ratio (BCR).

When mentioning the potential benefits of implementing the scheme, this can be related to overall developmental needs of the region from the earlier section of the masterplan. The benefits should aim at directly improving the situation from the issues mentioned earlier in the section. Crucially, this section is not a set of promises. It is important that the masterplan offers very general/high-level guidance/advice about choosing schemes. The possible variations in size, scale, design choices, and exact specifications of the intervention are large and should not be defined in the masterplan. The masterplan should offer an overview intended for planners to use when deciding on where to make future investments in the region. This needs to be tempered in the report to cover all the different benefits of each option, since with each scheme there will be extensive differences between possible implementations of similar technologies. Thus, when explaining the interventions, it is important not to offer a specific proposal and instead make loose suggestions of systems that may work to meet the objectives. In addition to this, the variety of developmental outcomes should be reflected with a wide spectrum of pricing in the masterplan.

As with the rest of the masterplan the guidance for the suggested strategies should be regularly reviewed to keep the common vision for the development of the ITS transport system relevant.

1.6 Indictive costings

The masterplan should describe and explain the indictive costings for each of the various unique interventions suggested. For each intervention the capital and revenue costs should be broken down.

1.6.1 Capital

The capital cost of a scheme is the initial start-up cost that is invested to begin the scheme. Large schemes will likely have a significant capital investment, especially if involving major construction works. However, factors other than the cost of design and construction can come into play; for example, road closures due to the ongoing construction work, or speed limited sections of carriageways will affect road users significantly. Mitigation may be put in place to try and avoid this since the effects of these factors on the local economy should be considered.

1.6.2 Revenue

Revenue costs are the funds associated with the yearly recurring cost of a scheme, after initial investment and project completion. For example, roadside equipment's regular maintenance which will often increase in cost from completion of the project, as with age and wear maintenance becomes more costly. When comparing different schemes' accumulative costs, the initial baseline capital investment (previous section) will vary, as would the revenue costs which tend to increase overtime. This may mean that a scheme with a larger capital investment may eventually cost less than a scheme with a lower upfront cost, if said scheme's revenue costs mean its cumulative total expenditure becomes greater. This could occur many years after the completion of a project.

This means that with each suggested intervention, the masterplan should explain clearly both forms costings with the various ITS technologies that could be required.

1.7 Cost benefit analysis

Using the information about the various strategic and local interventions as well as their indictive costings, the masterplan should summarise the Benefit-to-Cost ratio (BCR) of the proposed schemes. The benefits of the schemes would be focused on solving/mitigating the issues the intervention was highlighted as attempting solve. The masterplan may also contain higher echelon objectives that are achieved by outputs related to other issues. For example, an objective of improving prosperity in a region could be achieved by various improvements to the transport network which may involve ITS schemes/ strategies. Therefore, it would be important to consider the impact an intervention may have across the whole network.

1.8 Preferred list of interventions

Section 1.5 discussed the process for including the different strategic/local interventions that would be applicable to fulfilling the regional objectives of the masterplan that were derived from the common vision for developments in the area.

The section of the preferred list of interventions should offer guidance as to the highest priority of the discussed strategic/local interventions by explaining the reasons for selecting the schemes – largely because they offer the best Benefit-to-Cost ratio (BCR) for the specific region. This should be directly related the key requirements which aim to meet successful outcome measures in section 1.3 objective and requirement definition. However, it is important for the masterplan to avoid recommending schemes based purely on the BCR. It may be unwise to invest funds into a small scheme that affects a limited area or demographic group of road

users. Such schemes may have high benefits in a very specific location for reasonable capital investments. However, it is important to consider the network holistically since other solutions could offer a large output that has a greater impact on a larger proportion of the network. This could be considered more beneficial than a single 'high-degree' of benefit for a low cost in a smaller scale scheme. This means numerical reasoning cannot be solely responsible for selection of preferred schemes, other factors and intuition should also play a role.

Therefore, the masterplan should outline that a larger investment could have a much wider impact despite a lower BCR. This aims to ensure the masterplan offers more robust guidance which avoids looking at possible interventions in an overly simplistic manner. Other factors could include which issues the scheme aims to tackle, since some highlighted areas may be of a higher priority for development, despite offering more limited benefits in that particular regard.

2 Planning an ITS Intervention

The planning of an ITS intervention will lead to the success of that system throughout its operational lifetime. It involves setting the goals of the project and then managing all aspects of the design to achieve such goals. Although the output of any scheme varies, a design process behind them could follow a similar process. This document highlights and discusses high level steps within this process.

2.1 Understanding requirement.

A scheme may be developed to tackle a singular need or as part of a wider development plan. Whichever is true the scheme must be considered for what it should deliver for its own and the overarching needs of the situation and environment it will be within.

The first step of any design should be to understand the requirements from the scheme. The requirements may be directed within control of the scheme such as the client may request a scheme that deliver 100% real time surveillance coverage from road X to road Y. Although not a direct requirement for the output of the scheme external requirements from a masterplan or local residents may also include that the same system should utilise the same back-office system as other similar systems installed within the region or that any cameras have blanking zones for residential property. The initial part of any scheme should be to identify the requirements of the projects by discussing the required functional output with the Client and all stakeholders within the scheme area.

A requirement could be defined as:

- "a condition or capability that should be present in a product, service, or result to satisfy its specifications'' (Project Management Body of Knowledge).

 or

- Something that is needed or that must be done.
- A description of how a system should behave.
- A property or attribute of a system.

To allow the project team and Client to fully understand and measure the success of a scheme, requirements should be made SMART

- Specific
  - Goals should be specific. Goals help guide how we behave and think by creating and clarifying priorities.
- Measurable
  - Goals should be measurable. This allows goals to be tracked, to ensure progress is being made toward goal achievement.
- Achievable
  - Goals should be achievable. This taps into reality – is the goal realistic? Can it be achieved within the time frame given? Can it be achieved based on the employee's knowledge, skills, abilities, interests, strengths, weaknesses, and motivations? Can it be achieved at all?
- Relevant

- – Goals should be relevant. There are several types of relevance here. Like is the goal relevant to a scheme's role and responsibilities? Relevant to its capabilities and potential?
- Timely
  - – Goals should be timely. A goal should be achievable within the timescale available.

Where something captured within discussions with stakeholders may not be a requirement it can be captured as a desirable output. The process can capture the importance of these desirables and align them with a desirable importance level (i.e. 1-3).

The requirements and desirables of the scheme should be captured within discussions with all stakeholders affected by the scheme. Examples of stakeholders include:

- Client (including all parts of)
- Operator
- Maintainer
- Users
- Local residents
- Environmental groups
- Standards providers

General questions that may be asked in these sessions may include:

- What is the goal?
- What problem does your scheme resolve?
- What are the user's goals?
- What are the operator's goals?
- What are the maintainer's goals?
- What are the main drivers(priorities)?
- What are only desirable outputs?
- What metrics should the scheme be measure against?
- What are the constraints and limitations?
- Does this scheme sit within, work with or clash with other proposals?

These requirements should then be captured within a master document with all requirements and desirables identified as such, with desirables also given a priority level. Upon completion of this stage, and prior to any works in future stages, the Client will approve the requirements document.

2.1.1 Identification of standards

To resolve the issue identified within the previous stage the solution requirements will have been identified. As well as a scheme needing to fulfil these requirements, often regulatory bodies and agencies set minimum standards regarding how solutions, and/or contributary elements to that solution, to the requirements must operate. These standards are often overarching requirements put in place to protect the safety of users and operators and/or that systems work similarly by ensuring that all align to minimum requirements.

Once the issue and its requirements have been identified, the possible standards that the solution may need to adhere to should be identified. As a solution may not be known at this stage this section may need to be revisited within preliminary design. As the standards applied

may affect the solutions possible, the general standards that may shape which solution may be viable should be captured at this early stage.

2.1.2 Defined and agreed requirements

Once the requirements for the scheme and the overarching standards that will be adhered to have been identified the designer and client will discuss how these may impact on each other. Where the requirements (from all stakeholders) and/or standards do not align a consensus should be reached on which is the overarching requirement.

Once a final requirement and standards list has been reached, all stakeholders must formally agree to these.

2.2 Existing infrastructure, equipment, and location constraints

ITS systems are usually developed to resolve issues for existing roads, that being said the baselining of existing infrastructure and constraints is also true for certain elements of scheme on new roads as well.

Once the scheme's scope has been agreed, all schemes should assess and record any element that could affect the design of an ITS system. The designer should consider all aspects of the current site(s) details as well as anything that the ITS system may interact with. Capturing these details will provide the designers with information on what the proposed system could build upon, how any current infrastructure is utilised, how people use the existing infrastructure, and what is connected to the existing. It is important for the information captured to be recent and not historical data. Where the information available may be a few years old and could have been altered it would be important to assess this and update the historical data as required. It could be said that current infrastructure has 3 major components that should be captured and recorded:

- Site based information;
- Operation based information; and
- System based information.

Some information can be seen with the eye, but other pieces of information is only available from others. For example, the location and contents of an equipment cabinet can be surveyed by the designer but the location as buried infrastructure or how that cabinet is operated and maintained can't. Where information regarding any element of the site can't be captured by the design team themselves, they should contact the parties responsible for the required information to discuss the information required.

2.2.1 Site based information

Site based information may cover a single or several sites with the area of a site being as wide as it needs to be. The information requiring to be captured at any site will vary but all factors that could impact the design of an ITS design should be recorded. The type of information that should be recorded for any site may include:

- Location including GPS/Lat&long
- Pictures
- Explanation of what is there
- Condition of current assets
- Vegetation around the site

- If there is existing power supply
- If there is an existing communication supply
- Ground conditions

Additional points that others may have knowledge on

- Ownership of any existing infrastructure
- The purpose of the existing infrastructure and how is it operated to achieve this
- Buried services (electricity, gas, communications, etc.) around the site
- Sub surface ground conditions

2.2.2   Operation based information

Upon identification that existing infrastructure that may be part of a bigger system is at a proposed site of a scheme research must be undertaken to identify several factor surrounding it use and how it fits into the existing system. Examples of such systems would be CCTV, ANPR, variable message signing, etc. Apart from the overarching systems that gain information of controls the installation within your site the infrastructure on your site could be positioned there for specific reasons. Where such a system if existing at your site the design may wish to investigate points that include:

- Purpose of existing infrastructure
- Does that location cover a greater system requirement?
- Controls of any existing infrastructure
- The maintenance regime of existing infrastructure

This review of existing infrastructure should also capture the constrains on any future installation at a site.

2.2.3   System based information

Location based infrastructure can often be linked to a wider system and within understanding the existing setup and constraints that a system has for existing and future installations. A system may be delivered in two parts such as the physical input or output may be within a scheme site whilst the operating back office to that system resides in a central point remote to the scheme site, an example of this may be a CCTV and ANPR system. The scheme may not affect the existing system but look to add or upgrade the system. Hence, it is imperative that the scheme records what system is in place, its constraints on the proposed scheme, and if changed by the scheme how this may affect other physical infrastructure connected to it. Where such a system if existing at your site the design may wish to investigate points that include:

- What and where does the back office of the system reside?
- Who is the supplier of the system?
- What are the constraints of the existing system?
- What else is connected to or controlled by the system?
- What are the access requirements to the back office system?

2.3   Preliminary Design

Once the design team understands the requirements of the scheme and capabilities and constraints of any existing infrastructure and/or system the preliminary design can commence. The preliminary design will identify the possible solutions available to meet the scheme requirements. It should be noted that at times the solution may have been prescribed by the client and therefore captured a s a constraint. Where that has occurred, a curtailed preliminary design may still be required to assess the validity of the prescribed solution in lieu or now understanding all factors regarding the existing installation and site(s).

Where the solution has not been set by the Client, the preliminary design will consider all possible solutions that could be suitable to meet the requirements agreed. The design should be advanced to a position to allow the Client to fully understand the positive and negative points of each possible solution and select a preferred solution. To allow this the preliminary design should give outline position and quantities and costs of each solution.

The output of this stage should allow the Client to compare the preliminary designs for each solution and consider their preferred option. The preliminary design review document produced by the designer should as a minimum encapsulate for each solution:

● Where the proposed solution does, doesn't, and exceeds the requirements of the scheme
● The capital and revenue costs of the solution
● The benefit to cost ratio
● In comparison to other solutions, what are the benefits and negatives of the solution
● Where the solution has an effect on an existing system or stakeholder
● Delivery timescales
● Number of suppliers
● Environmental impact
● Health and safety of all users

2.4   Stakeholder review and agreement

With the preliminary design review available, the Client must consider which option they would prefer to progress. The Client may request additional information regarding each solution which could either be supplied from the existing design or may require additional design. Only following approval of a preferred solution by the Client should the scheme be progressed to the next stage.

2.5   Detailed design

Within the detailed design phase, the preliminary design is taken to a higher and more detailed level. The detailed design should design the scheme such as the design is suitable to be included within a Works Information for a Contractor. The detail within the design should leave no element of design on aspects that could affect the scheme in Construction, in handover into operations, and throughout its operating life cycle.

This element of the scheme could be moved onto a Contractor such that they undertake a design and build contract. Even with a design and build contract, the designer should always consider how the works of a Contractor would be brought back into operation hence the designer much has provided sufficient controls and constraints within the contract such as that integration and operation are as expected.

Due to various reasons, during detailed design, it may become clear that the proposed solution may not be able to meet the scheme's requirements. Where this occurs, the designer should organise a risk reduction meeting with the Client to discuss these non-conformities. The Client could accept these non-conformities, ask for redesign, ask for wholesale change in the solution and return to preliminary design, or consider the suitability of the scheme. Whatever the output, the designer should gain written confirmation or the output for each risk discussed.

2.5.1 Construction

The detailed design phase will develop a design such that a construction Contractor will have all information to undertake their work. Where information is not available the designer shall agree with the Client that this is acceptable and inform the Contractor that they will be responsible for this element and risk associated with it. It should be expected that the designer provide information regarding all elements for the design including sufficient information that the Contractor understands any construction limitations and constraints. The detailed design should provide all information to construct on elements including:

- Pavement
- Structures
- Environmental constraints
- Drainage
- Electricity supplies
- Communication systems
- Technology infrastructure
- Environmental constraints

2.5.2 Integration

Further to detailed construction information, the design shall consider and provide full information to the Contractor or how the system will connect and integrate within any existing system.

The detailed design should provide all information to integrate the scheme into the existing system which as a minimum will include:

- Timings
- Synchronisation
- Control and communication protocols
- Overarching system limitations or controls

2.5.3 Operational

Detailed design is often considered to be about construction and getting the system operational, but it should always have the operational requirements within its core. The operational phase of a scheme is almost always longer than the design and construction phases, but operational outputs can be limited by failings in the predecessor phases.

The designer should consider all aspects of how the scheme will operate and how the system will adhere to the operational functional requirements at each step through its lifecycle. Within detailed design the designer should discuss the proposals with all stakeholders that will have a role in or be affect by the operation, maintenance, and ownership of the scheme. The designer

will gain approval from all stakeholders that will operate the scheme once in the operational phase.

The detailed design should provide all information to operation of the scheme throughout its lifecycle which as a minimum will include:

- Adherence of the proposals to the functional requirements
- Maintenance requirements
- Health and safety of all users
- Overarching system limitations or controls

2.6   Design Approval

Following detailed design, the designer will issue the design to the Client for their review. Following their review, the designer may be questioned on certain aspects of the design. To satisfy the client on these queries, it may require the designer to provide further information or explanation of their design or require the designer to return to detailed design to make amendments to the proposals. Upon the Client's acceptance of the detailed design, they will take ownership of the design and progress the scheme to the procurement phase.