Information Requirements

What Information should be in your information requirements at **Organisational, Function, Asset, Project and Business** levels and how to create them.

Iain Miskimmin

IADD4UK/ COMIT Projects Ltd

8th April 2021

A guide written from the legacy experience of the Infrastructure Data Dictionary for the UK group (2013-2018)
Updated with reference to recent standard introductions (2021)

Contents

COMIT Projects

LinkedIn IADD4UK page

Iain Miskimmin

Information Requirements

The following guide was put together from discussions and knowledge share through the Infrastructure Asset Data Dictionary for the UK (IADD4UK) group between 2013 and 2018. Updated where appropriate to include the most recent standards and some additional thought leadership.

IADD4UK

The IADD4UK initiative was formed of the foremost owners, major projects, delivery partners and interested parties under the chairmanship of the COMIT innovations group. A list of participants can be found at the rear of this guide.

Early in our BIM journey it was recognised that data and its slightly more refined form, information would be the key. We had standards as how to classify it, manage it, secure it, procure it, exchange it, but nothing about what "it" actually was.

It was also understood that this required information would have an impact on everything we do with our assets, across the entirety of its lifecycle. That impact had a relationship with the outcomes delivered to their respective clients, whether that was an end user, consumer, member of the public, a shareholder or the country itself. The delivery of the outcomes ensured that there was a value in the information, without which their upkeep would not be possible.

The IADD4UK group was put together with an agreement to research and document the best way to create information requirements, not to write them, but it was agreed that if organisations could come together when writing them, the costs and risk could be shared and the benefits doubled.

The reason for increased benefits, were that when assets were transferred from one owner to another, or between delivery partners they would be described in the same way, negating the risks of translation and converting information from one system to another. Key assets in infrastructure are basically the same, whether they are owned by a transport, communications, energy or water company. They will have the same questions, tasks and decisions during their lifecycle. The answers will be different, but the basic information requirement will be largely the same. This commonality across owners could help reduce the procurement costs and the risks of generating, managing and exchanging each information set with the side effect of reducing interoperability issues between software packages.

In 2017 the IADD4UK organisation was put on hold for various reasons, chiefly lack of funding to both create and curate a common information requirements dictionary. This meant that the participants in the initiative dispersed to create their own data dictionaries utilising some of the methods and processes shared with you in this guide.

To set the scene and context, it is important to define some of the background knowledge gained during the meetings and surrounding research.

BIM, Digital Twin and the Rorschach test

When BIM was truly launched in the UK with the government mandate, there were already many people and organisations doing something that could be classified as such and each of those entities were doing something slightly different. The BIM that the UK Government wanted to mandate by 2016 was not something fully defined but could be interpreted depending on your point of view in many different ways. Like the Rorschach test, your own interpretation was driven by your personal skills, experience, business needs and interests.

It was clearly understood by the members of the IADD4UK group that BIM was not technology, but a set of methods, standards and processes set out to create information that would have a purpose, a function and be trustworthy and to do this we needed all parties that contribute to the creation of the BIM model (or Digital Twin) to follow the same rules, so that whatever their interpretation, we had a valuable digital delivery.

In 2013, we agreed on a definition of BIM, that likened it to a "Google" for their assets, with the big difference that the answers coming back would be focused and trusted! So in essence, it would be a federation of data, in whatever form it appeared, stored in many different systems, linked by some form of digital backbone that could search all the systems and return the data that was relevant to the question typed in and the person that typed it.

The term Digital Twin, started to appear just as the group was shutting down, but we adopted the Institute of Civil Engineers definition, that took our original BIM explanation and added two important factors. Firstly, that our assets aren't isolated, but interact and impact on others at many levels, and this interaction will have an affect on the answers we receive. Secondly, the need for a two-way bridge between the physical and digital worlds. So that sensors or similar could update the data held in the digital asset and that to optimise the operation of the physical, the digital asset could control elements of the physical asset through actuators.

Taking this interaction a stage further, the infrastructure asset owners in the group recognised that at some point, at a time of national need, perhaps through writing a future infrastructure strategy or reacting to a national disaster, they would need to bring their digital assets together. This is now recognised as the National Digital Twin and having a common asset data dictionary would have had a significant positive impact, but alas this is not the current situation.

Value

Whether your focus is on value of BIM or Digital Twin, they both boil down to one key ingredient, *data*. These pieces of data have to be trusted and well managed as well as being handled correctly giving them meaning so that they become information, which, when given context becomes knowledge and finally when applied to resolve a problem, task, decision or question becomes wisdom. At each step, that data becomes more valuable to its user and supplier.

There is a great historical example of this through the work of Abraham Wald, a Hungarian-Jewish statistician did during the second world war.

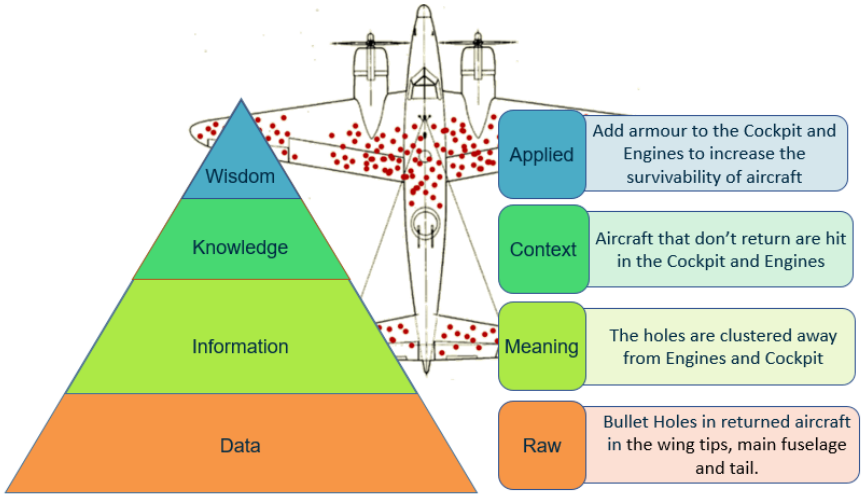
Early in the conflict it was noticed that many of the aircraft returning from missions over occupied Europe had a significant amount of bullet holes and damage in the wing tips, main fuselage and tail. Scientists originally concluded that these were the areas that were being targeted by the enemy and so therefore the most vulnerable and should be armour plated. This was an obvious but very erroneous conclusion.

Abraham Wald pointed out the critical flaw in their analysis by looking at what that raw data meant, giving it context and applying it. By which he markedly increased its value.

Instead of looking at where the holes were, he understood the meaning of this data; that those aircraft returning safely were not hit in the engines or cockpit. Meaning that aircraft could take substantial damage in these areas and survive.

Putting this into context, it was realised that those aircraft being shot down, were most likely being hit around the cockpit and engines.

Finally applying this knowledge, they set about putting armour plating around the cockpit and engines which greatly increased the survivability of the aircraft. This sequence had turned simple raw data into wisdom.



The increasing value of data in Abraham Wald's WW2 analysis

This is a great example, but we need to delve into that raw data a little further. No matter how good it looks, the value of that data is based on whether we can find it amongst the huge volume presented to us on a daily basis and when we do locate it, can we trust it, or are we going to have to do some sort of time consuming validation exercise?

I would hope that by now most people interested in BIM and Digital Twin will have heard of the NIST (National Institute of Standards and Technology) report from 2008 which stated that an engineer's time was wasted up to a level of 40% searching for and validating information? In 2017, the COMIT team undertook some anonymous interviews and research in Europe and due to the increased volume of data and the reliance on digital means found that this could be as high as 80%! Potentially 4 days in every 5 being used to find

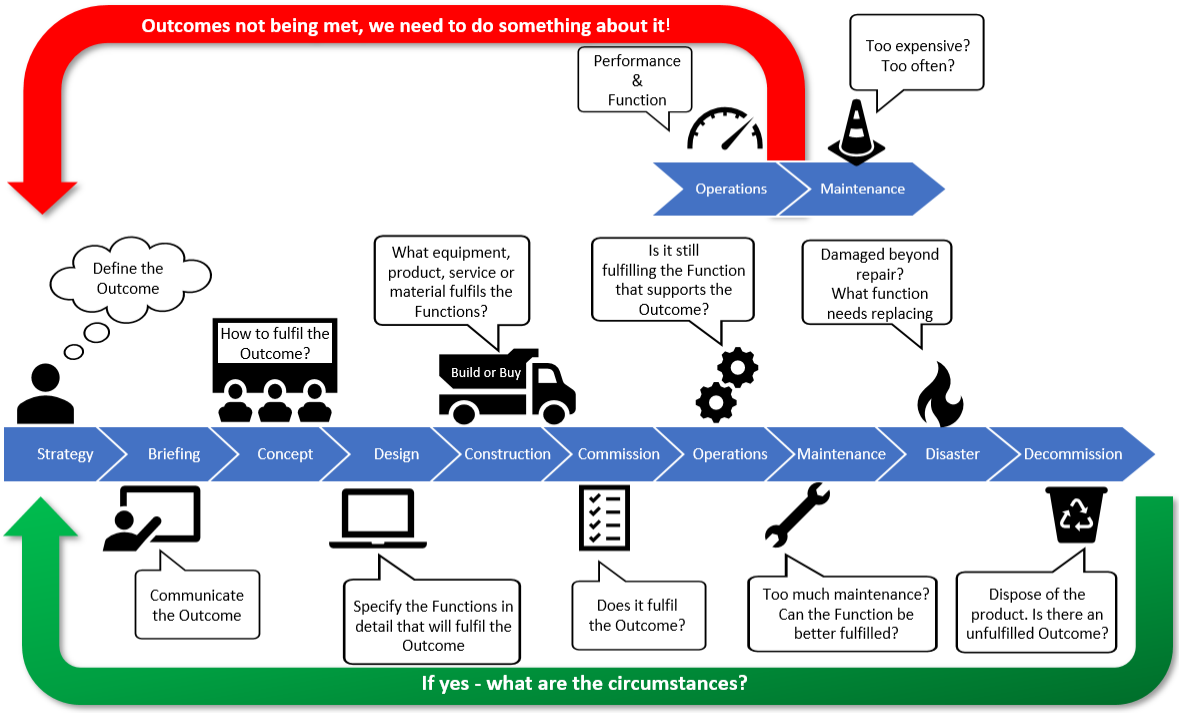
information because it wasn't well managed or classified and then validating it because they justifiably couldn't trust what they saw.

The BIM standards at the time the IADD4UK group were formed were focused on the delivery partner in the CAPEX phase and gave scant guidance or rules for the client organisations. These were provided in the Government soft landings documents, but it appeared seldom understood or acted upon.

This situation improved with the publication of the Gemini principles in 2018 guiding clients towards a value driven digital requirement, setting out guidance on how they can define a valuable set of data that will form the basis of their Digital Twin.

The key with all the data collected (defined in the asset data dictionary) is that it has a value to someone at some point during the lifecycle. That value increases and decreases depending on who that end user is and at what part of the lifecycle they interact with the asset. But as clearly pointed out in the Gemini principles, if it has no purpose, cannot be trusted and cannot function as intended then it may have no value in being collected, curated and communicated.

The reason that the PAS 1192 and the subsequent ISO 19650 series of standards are being required by the client organisations is not just because they are the BIM standards, but because they ensure the above value is upheld. Poor information management will devalue any data that has been procured during the lifecycle of the asset.



Lifecycle

The data that we define in our asset data dictionaries and the various information requirements packages has an impact from a very early stage, perhaps even before we realise.

Decisions and the data that triggers the need to make them are part of the day to day running of an asset. Your existing asset portfolio has a requirement for data that will tell you if it is operating efficiently, functioning as the specification and not costing a fortune to maintain.

This early trigger information is of paramount importance and perhaps some of the most valuable. Giving us the ability to look at data trends to better predict interventions and future budget requirements.

It was recognised by the IADD4UK group of clients that when it was identified that an intervention was needed, the type of intervention was also at the mercy of political, financial and other market force data, that needed to be identified and associated with the asset.

An asset data dictionary would then set out the information requirements for the various stages of the project, ending with commissioning. This set is important to highlight, as it not only covers how to commission the physical asset but also the digital asset. Ensuring all the information exchanged with the client is correct and that it is valuable in accordance with the Gemini principles of purpose, trust and function.

The IADD4UK team identified that a specific data set for disaster as missing from the standards and that at a moment of crisis, the expedient delivery of clear, concise and trustworthy data to help mitigate the incident and speed up recovery would be a very valuable addition.

Data Quality Framework

Whether data is for CAPEX or OPEX it needs to follow some basic rules for it to be valuable. In 2014 the Bank of England set out five dimensions for measuring quality in their Data Quality Framework document which are applicable to how we value data.

- Relevance
- Accuracy and Reliability
- Timeliness and Punctuality
- Comparability and Coherence
- Accessibility and Clarity

Relevance

This is the degree to which the data meets the needs of the end user. Whether that end user is part of the operational, the delivery partner or the consumer if the data isn't relevant to their needs then it has no value to them. On the flip side to this, if that data is exactly what they need to carry out their primary task in meeting their company objectives, in an easy and efficient manner, then it could be exceedingly valuable. When we see the term "Level of Information Need" when referring to data mentioned in the BIM and Digital Twin standards, this perhaps could be read as "Level of Information Value".

Accuracy and Reliability

A piece of data needs to be as accurate as it is needed to be by the end user. There is little Value in having a sub millimetre accurate laser scan of a stretch of blacktop on the highway.

The more accurate you make something the more it potentially costs to generate, verify, manage and distribute. If data is both relevant and accurate enough for the end user to carry out their primary task, then it is worth more.

The less I can rely on a piece of data to help me make good decisions, the less I value it. As the Gemini principles point out, trust has a significant value of its own.

Timeliness and Punctuality

If I need to carry out a construction activity on a specific date or need to make a financial decision before a public enquiry, I will need the relevant, trustworthy data before that deadline, so it can help me. If it arrives late then it's value can be little or nothing.

Comparability and Coherence

Comparability increases our understanding of the data in front of us and puts it in the context of its historical or intended values. For example, it lets us know if the data is within an acceptable range, or whether it indicates a gradual degradation over time. This not only allows us to ensure our business is moving in the right direction to achieve its objectives but also to ensure our assets are performing as designed. Comparability increases the value of data through context.

If data isn't coherent and we struggle to understand it, the chances are we will ignore it and search elsewhere for an answer or we will waste a large amount of time trying to work out what it means. Leaving that data worth nothing!

Accessibility and Clarity

No matter how relevant, accurate, punctual, comparable and coherent the data, if it not accessible to the end user at the time they need to utilise it, then it might as well not be there! Alongside this the data needs to be presented in an unambiguous way that supports and promotes any associated data. When we want to listen to music whilst travelling on public transport, we will probably use noise cancelling earphones, removing the white noise and just presenting the sounds we want. That same process is needed to strip out the masses of data that is just white noise and give us the clarity needed to make quick decisions.

The Human dimension

When considering data for our BIM and Digital Twin models, we can be forgiven for concentrating our efforts around what has been generated by technology be it hardware or software. This does however miss out a large volume produced by humans, whether this is exchanged in a digital way or simply by physically talking to each other.

When dealing with human generated data we must keep in mind how it can be verified as true. In recent history much has been made of False News, delivered over social media platforms to deliberately mislead or influence the population, who might not know any better to the wrong conclusion. This could be done for many reasons, not many of them for the good of society!

To this end, to ensure that human generated data is valuable to its consumer, the following should be taken into consideration:

- **Provenance** - *Are you looking at an original piece of information?*
- **Source** - *Who created the original piece of information?*
- **Date** - *When was the piece of information created?*
- **Location** – *Where was this piece of information created?*
- **Motivation** – *Why was the piece of information created?*

These checks against human generated data, could be equally applied to any data in an existing system to verify that it has a level of reliability that ensures the information inside your existing business and asset information models can be trusted and therefore has a value.

Information Requirements

In the BIM/ Digital Twin world, a complete asset data dictionary contains all four defined information requirements and in the course of the IADD4UK work we defined a further one, Function Information Requirements with the help of James Heaton from Costain/ Cambridge University. Below are the descriptions used by the group for each of the information requirements, which we will explain how to generate in later sections.

Organisational Information Requirements (OIR)

This information helps a business or organisation to ensure they are delivering the outcomes which they have been set up to support. Whether that outcome is about finances, the environment, the service delivered to the customer, their reputation or the part of society that it needs to enable, this information will help them to progressively assure throughout the organisations activities that they are either on track to deliver or have completed delivery of the organisations objectives.

This information can come from a plethora of business systems, such as:

- Enterprise Management
- Financial Management
- Facilities Management
- Equipment Management
- Employee Management
- Information Management
- Customer Development
- Product Development
- Supplier Development
- Operations Management
- Service Management
- Improvement Management

The OIR is key to helping the IT department of any organisation understand which pieces of information are valuable and need to be exposed through a reporting system. Keeping the expense and complexity of integrating multiple disparate systems to a minimum.

Asset Information Requirements (AIR)

This is the information that answers questions, helps makes decisions on and carry out tasks in respect to an asset. Starting with either the need to replace, upgrade or decommission an existing asset, all the way through the lifecycle. In the early stages, these pieces of information will be less granular and more about specifying the function and performance required in the design and in the physical thing that will perform the duty.

The starting point for this would probably be something like a Uniclass 2015 classification table that will give an asset type. The AIR will then list what information is required against this type of asset whenever it is deployed.

As this information is being gathered from multi sources and suppliers, the AIR will need to specify not only what that information should be, but how it is defined, what units it is presented in, what format it should be and if possible a picture to show what it means.

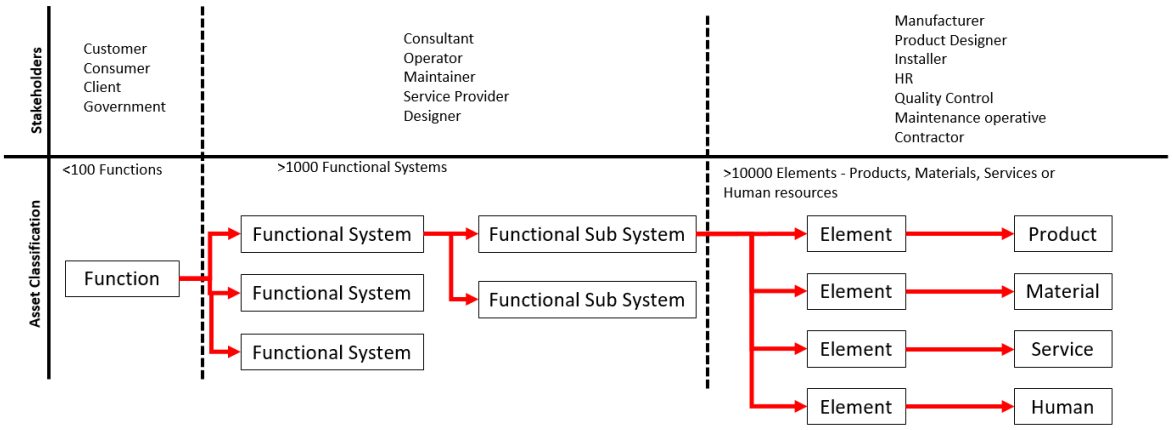
It may be advantageous to have a generic entry in the AIR that has information requirements common to everything. This was investigated by the IADD4UK group and the concept of the Asset Tag set of data was borrowed from the Crossrail project and enhanced to cover more ground. This will be covered later in this guide.

Function Information Requirements (FIR)

It was understood by the IADD4UK group that the delivering a full AIR was a very large task and for those with restricted time and budget it may be better to start with the Functions, define them and set out their information requirements. These functions have a direct relationship to the outcomes that the project or organisation are trying to achieve.

Whilst a major asset such as Crossrail had close to a million individual assets, it had less than 100 functions. Which meant that defining them and the information we need to create and curate for them is significantly smaller, but still has a high value.

It was demonstrated through the work of James Heaton that this reduced the overall effort considerably but retained a very high value deliverable.



Project Information Requirements (PIR)

In the original PAS 1192 standards, the information that was needed for the delivery of the CAPEX phase was described in the Employers (Exchange) Information Requirements and not

as a separate package. It is recognised that with ISO 19650, that this is addressed with the PIR, which is an improvement, due to their being much non-asset information being needed to deliver progressive assurance to the financer, insurer, end user, client and owner that they will be receiving both a physical and digital asset that will perform the function and deliver the purpose that can be trusted and therefore valued by them all. The PIR is generated in the same way that the OIR is but will probably access multiple documents from different sources.

Exchange/ Employers Information Requirements (EIR)

The definition of this has undergone many changes from the early stages of the PAS 1192 standards through to the ISO 19650 suite. How to write an EIR was not part of the IADD4UK remit, but many of its members were involved in writing the 7 Questions methodology for its generation. The workflow of which is reproduced at the back of this guide with the kind permission of the COMIT team.

Financial Information Requirements

Perhaps one of the less considered, but ultimately one of the most valuable types of information is the set required by the financial institution to better understand the risk they are taking in lending the money for the owner to build a new asset! The higher the risk, the higher the interest rates set out by the lender. **If the asset owner, in conjunction with the financial lender can define this information and allow it to be monitored during the lifecycle of the loan, then the overall cost of building a new asset could be significantly reduced.**

Insurance Information Requirements

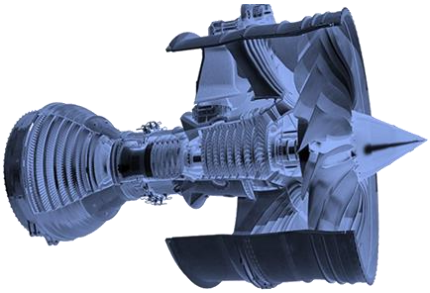
In the same manner as the financial information requirements, another large cost for the project is insuring the risks taken during the CAPEX phase. If the information needed by the insurers to understand the risks and what is being done to mitigate them on a day to day basis, is defined and monitored at an agreed rate, then this can also see a significant improvement on the costs. Just like a learner driver has a device in their vehicle to monitor acceleration, movement and speed, that has an impact on their car insurance.

Outcome Driven Procurement

Outcome driven procurement is a key topic that was raised as the UK started on its digital revolutionary journey. It was laid out in the Government Soft Landings document, but like many publications of its ilk, is left on the shelf by too many client organisations.

I see this procurement strategy as a WIN-WIN-WIN situation for End User-Owner-Supply chain, but it can be difficult to articulate in a contract, especially to a level that is enforceable in our existing contracting culture.

Some great examples are out there, such as a well-known supplier of aircraft engines. You don’t buy one, but you do purchase pounds of thrust per minute in the air. This means that when it’s not delivering value to the owner, it’s not earning money for the supplier.



So, what does that mean?

- The **End User** should have less delays, risk and cost to their journey
- The **Owner** knows they are going to get a good quality product that won't break down and when it does, a repair team will be there fast to fix the problem. It also means the maintenance regime is at peak performance to get the best out the asset (Engine)
- The **Supplier** has a long-term cash flow that is guaranteed, as long as they supply the outcome. This gives them a healthy order book, pushing up the value of their company and safeguarding jobs.

But that's in Aerospace, how would that work in civil engineering?

There is an excellent example of how this would work in a highways context just down the road from where I live.

The highway in question is a single width lane with passing places, it rises on a slope up to various properties with fields and woods either side. Through lack of maintenance the drainage ditches on either side have long filled with leaves and debris leading to all the water that runs off the nearby fields and woodlands using the road as a streambed. This water flows down the road breaking up the surface and causing potholes, some of which are very deep. This of course does not give a good or safe ride for the end user. Every year the council pays a contractor to fill in some of the potholes with tarmac which washes out within a few weeks depending on the weather.

This costs the owner every year with reputational damage and also financial damages claimed by road users. The supplier or contractor's hands are tied as they are only engaged and paid for a small amount of tarmac and the time it takes to fill the hole, yet their reputation is greatly diminished as their name is linked to a poor road surface. So we enter into an endless cycle that is beneficial to nobody.

What would be the outcome?

"To have a safe and comfortably driven on surface for the road user"
When the road user complains that this isn't being achieved, the owner will stop paying the supplier until it is fixed. The better option for the supplier is to spend a small amount of time and money digging out and clearing the ditches in the autumn to ensure they aren't clogged with leaves. This way the water flows down the ditch, not the road, ensuring it achieves the outcome all year around. I'm sure the same could be said about Ironwork and other street furniture also.

- The **End User** has a safe and comfortable experience where they don't damage themselves or their vehicle.
- The **Owner** has a better reputation for ensuring their highways are kept well maintained, will save money on End Users insurance claims and also materials which come at both a financial and carbon cost.
- The **Supplier** has a long-term cash flow that is guaranteed, as long as they supply the outcome. This gives them a healthy order book, pushing up the value of their company and safeguarding jobs.

Digital Contracts

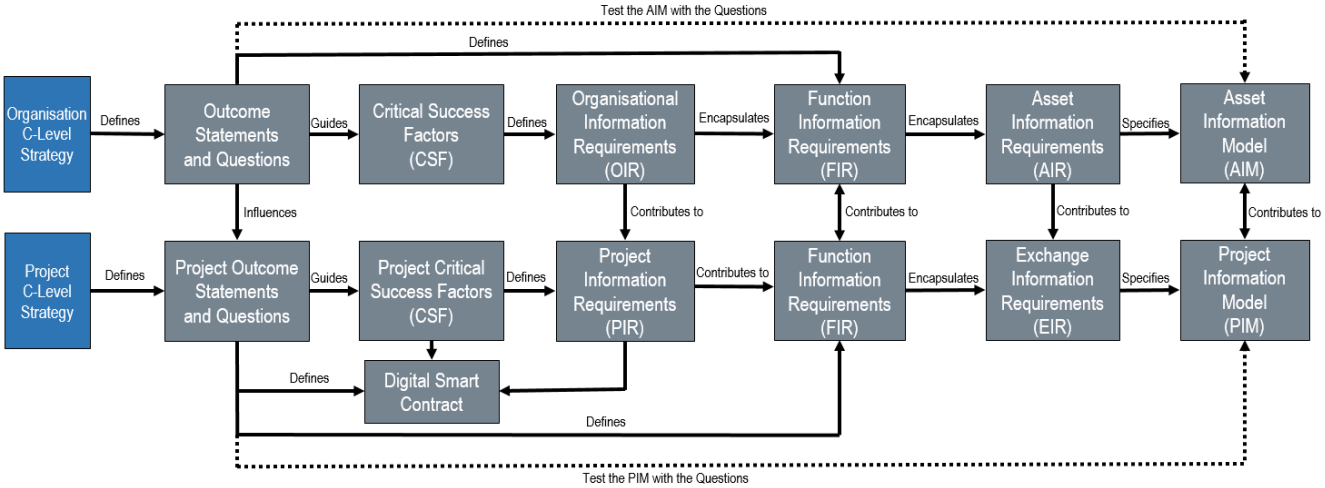
It's been long recognised that contracts have become long winded, complex and only decipherable through employing a lawyer to interpret them. This complexity will increase the risks in the project and also the chances of each party's legal team interpreting it in different ways, leading to costly disputes in court that don't benefit either client or delivery partner. Putting it in a military context, when given a mission, everything stated during the orders group is a positive clear statement on how things will be done, so as a team we achieve the commander's (client) intent and there are no misunderstandings that will lead to failure of the mission. The more complex the execution (or contract) the more risk of failure!

The answer is really to shorten the contract, so that it gives clear, positive guidance, rather than confusing complex clauses in a language that normal people can't understand.

Technology is starting to help in this area, by instead of writing a document, the contract should be a database of Outcome Statements and their associated Critical Success Factors that can be searched and queried. This could still leave things open to interpretation of the search results. So, in this matter technology could come to the rescue again in the shape of artificial intelligence giving a single interface to the contract database. This would allow anyone, whatever their level of legal understanding to ask a simple plain language question of the contract and get a clear, concise and consistent answer.

Imagine the current scenario on site, when a sub-contractor has an issue that has potential contract implications. Instead of having to engage the legal team and await their interpretation, that site operative can simply ask a question into their mobile device and get a legally correct answer that they will understand!

The key is to make the contract simple first, then collaborative and then digital. There is no point in digitising a complex contract as it still can't be read or understood either by humans or computers. IADD4UK understood that the outcomes that are generated to produce the Project Information Requirements package, should be used in setting out a smart digital outcomes based contract.



Defining Information Requirements

The following methodologies can be used to create the various IR packages.

Organisational and Project Information Requirements

Show me the money! Which is sadly one of the main requests that goes unfulfilled when we talk to C level executives about BIM and Digital Twin.

One of these executives will have written a fabulously worded strategy, telling the world how amazing things will be and the targets they mean to deliver to their stakeholders. But how does this document setting out their dreams for running their existing assets or delivering the latest major project translate into sold information requirements that we can measure and monitor. Information that will allow that C level author to know that the organisations charged with its delivery are on track to meet those promises is valuable to them and your leverage to persuading them that they need to invest in information modelling.

So how do we get from a high-level document executive document down to an Organisation Information Requirement (OIR) and or a Project Information Requirement (PIR) whilst supporting a smart digital contract based on outcomes?

This starts with an executive strategy document. An example of which could be the Poland's CPK transport strategy, which includes a new airport.

3 column deduction

To properly extract information out of a document, I have always used the 3-column deduction method, which basically asks the question "So What?" twice over!

So what? So what?

Extract out main points	What does that mean in plain language?	Critical Success Factors
• This is word for word extraction from the strategy document • Number these extractions MP001, MP002 etc	• There may be many of these to each main point • These are "Outcome Statements" • Number them OS001, OS002 etc • Create a Question from each statement that can be used by executives to test your AIM later. • Number them PLQ001, PLQ002 etc • These statements should follow the SMART objectives format and may be used in the contract. • Prioritise them if you can, this will help you spend the money in the right place!!	• Try to limit this to 5 or less for each OS • Number them CSF001, CSF002 etc • How can they be monitored & measured? • Create granular Plain Language Questions for use in commissioning the digital assets and test to a more detailed level. (number them)

In the first column you should extract out the main paragraphs from the strategy document. These are word for word, broken up into manageable chunks. Each of the main points is given a reference number and it might be worth if it is a large document to note down the page and paragraph they were extracted from.

You'll notice everything has a unique identification number, so that when this data is placed into a database, we can track what links to what and start to use machine learning to automatically generate things in the future. Start your ID with the letters MP.

Extract out main points	
• This is word for word extraction from the strategy document • Don't pick too much! • Number these extractions MP001, MP002 etc	MP001: The CPK should be located less than 50 km away from the city, in a place allowing for railway access in a time not longer than 20-30 minutes.

Now ask the question: So What does that mean in plain language?

As an engineer, you will be a practical, straight talking person, so your job is to translate that marketing flowery main point into something plain language. You may find that there are multiple of these per main point, which is fine.

When you write these plain language outcome statements keep the principles of SMART in your mind:

- A Specific goal has a much greater chance of being accomplished than a general goal
- Establish criteria for Measuring progress toward the attainment of each outcome
- Check to make sure its Attainable and not impossible.
- Check to make sure it is Realistic with current technology, materials, skills, timeframe and economic climate.
- If at all possible, the Outcome should have a Timeframe in which to achieve it or during which it needs to be upheld.

Give each **O**utcome **S**tatement a unique ID starting with the letter OS.

From this outcome statement, craft a question that will help to test this outcome against the information requirements and your Asset Information Model or Project Information Model. These questions are used at the C Level to ensure their strategy is being carried out.

Once you have all your Outcome Statements, it will be worth assessing them for priorities, to make sure you concentrate on the more important ones. Use a simple Very High to Very Low, but don't give the option for moderate, as it will not encourage a good thought process for the assessment!

What does that mean in plain language?

- There may be many of these to each main point
- These are "Outcome Statements"
- Number them OS001, OS002 etc
- Create a Question from each statement that can be used by executives to test your AIM later.
- Number them PLQ001, PLQ002 etc
- These statements should follow the SMART objectives format and may be used in the contract.
  - A Specific goal has a much greater chance of being accomplished than a general goal
  - Establish criteria for Measuring progress toward the attainment of each outcome
  - Check to make sure its Attainable and not something that will never be possible.
  - Check to make sure it is Realistic with current technology, materials, skills, timeframe and economic climate.
  - If at all possible, the Outcome should have a Timeframe in which to achieve it or during which it needs to be upheld.
- Prioritise them if you can, this will help you spend the money in the right place!!

OS001:
Airport should be under 50kms from the city centre allowing a journey time of 30 minutes. (High Priority)

PLQ001:
How long is the journey time between the city centre and the airport?

Now ask the question one more time. So, what Critical Success Factors do I need to measure and monitor this outcome?

Don't be afraid of Critical Success Factors, they really are a just simple high-level goal that is imperative for a business to meet, a good guide is that they must be:

- **Vital** to the outcome's success.
- **Benefit** the organisation or project as a whole.
- Synonymous with an Outcomes **goal.**
- Link directly to the business **strategy**

There may be many of these but try to limit it to 5 per outcome statement and make sure once again that they have a unique ID, so we can track them back to the main point in the executive strategy document.

Critical Success Factors:

A CSF is a high-level goal that is imperative for a business to meet it must be:

- **Vital** to the organisation's success.
- **Benefit** the company or department as a whole.
- Synonymous with a **high-level goal.**
- Link directly to the business **strategy**

- Try to limit this to 5 or less for each OS
- Number them CSF001, CSF002 etc
- How can they be monitored & measured?
- Create granular Plain Language Questions for use in commissioning the digital assets and test to a more detailed level. (number them)
- Combine these with the Outcome Statements to create your clauses in a smart digital contract.

CSF001:
Distance from airport to city centre is less than 50km.

TOIR001:
Measure track length from city centre station platform to airport station platform

TOIR002:
Measure track length from airport station platform to city centre station platform

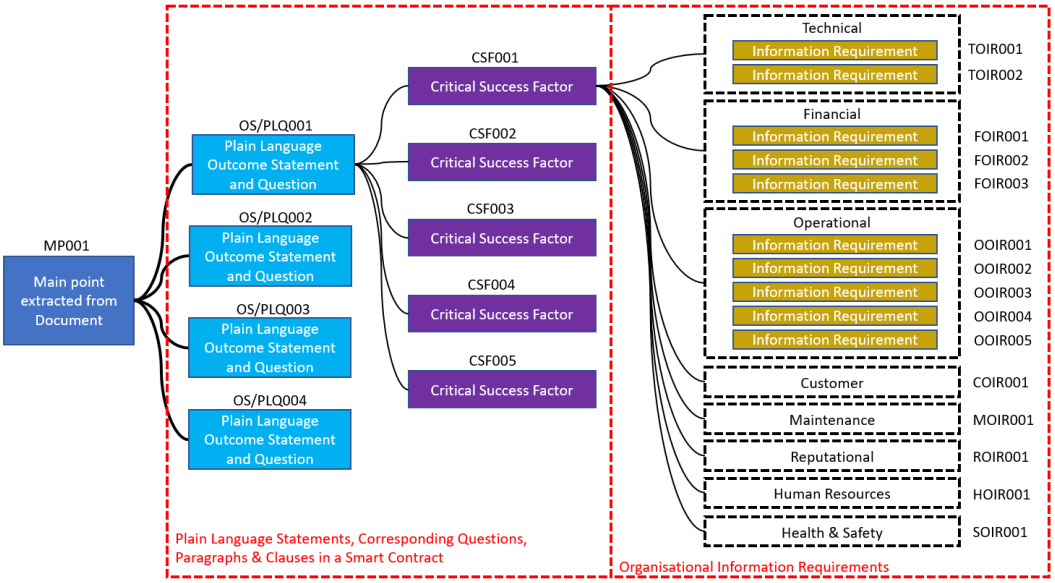
CSF002:
Journey time from airport to city centre is under 30 minutes.

OOIR001:
Measure journey time from when train closes its doors on the city centre station platform and when they open at the CPK station platform

OOIR002:
Measure journey time from when train closes its doors on the CPK station platform and when they open at the city centre station platform

Create a plain language question to be used when commissioning your digital asset. Can you answer the question and trust the answer? If yes, then the digital asset is fit for purpose.

These Critical Success Factors and the associated Outcome statements can be used to create the basis of your smart digital contract. Your final job is to document how they could be measured and monitored.



These pieces of information that will help you measure and monitor the performance of the Critical Success Factors will come in various types:

- Technical
- Financial
- Operational
- Customer
- Maintenance
- Reputational
- Human Resources
- Health and Safety

As you can see each of these are the information requirements that will make up the OIR. Good practice tells us that each must have a unique ID that reflects the type of information it is. Allowing us to track this information requirement back to the executive strategy and also allowing a change management process to take place when the executive strategy is rewritten.

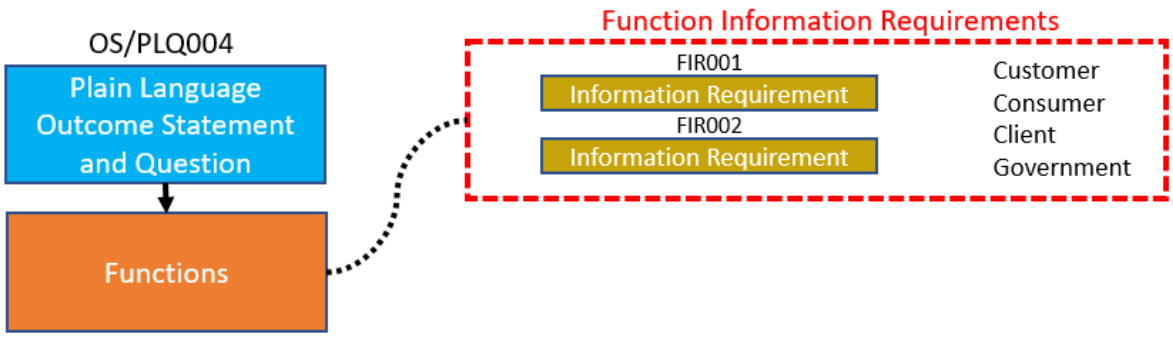
Function Information Requirements

Each of the Outcomes defined in either the OIR or the PIR, will have a set of functions that are needed to deliver them. These can be set very early on in the OPEX process and so the information that is set against those functions can be defined and collected sooner, making their impact on early decisions more valuable.

This information will primarily impact the customer, the consumer, the client and the government due to its high-level nature.

The key to defining the Function Information Requirements is understanding what is needed to define that function and measure and monitor its performance. Setting a threshold that will tell the information model whether it is starting to fail or has already failed to deliver the key function that will support the outcomes set by the organisation or business.

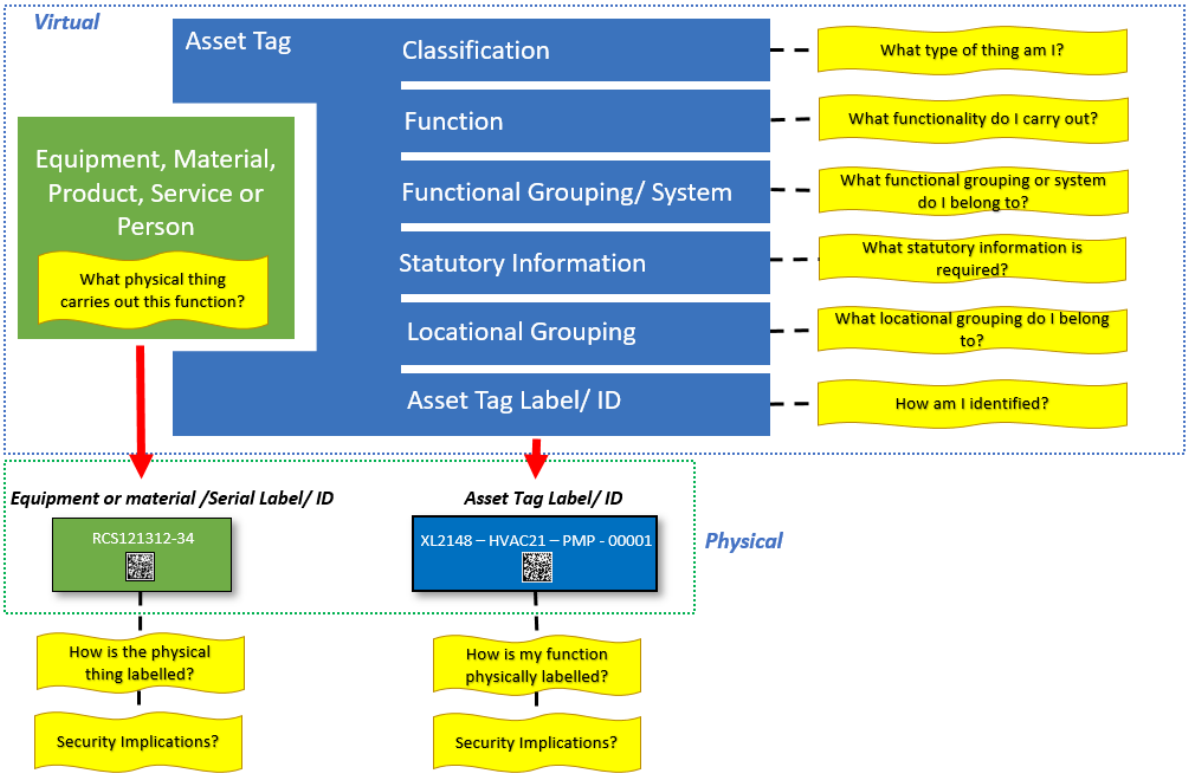
If you have previously used the Asset Tagging methodology pioneered by the oil and gas industry and enhanced for infrastructure by Crossrail, then you will already be ahead of the game with these.



Asset Tagging

This isn't about how we label things but is a set of information gathered at various early stages of the asset's lifecycle that will help define the function and some of their information requirements, (including the duty of the asset), before anyone has even thought about the physical thing that will fulfil it. The Asset Tag helps to define the need and reserves the space with a unique identifier in both virtual and physical worlds.

This asset tag is not a physical label, or randomly assigned number in a CAD system, it is a basic set of intelligent data that helps us to make those good decisions.



Classification - I need to know what type of thing I am because:

- It creates a common understanding as to what I am.
- It helps to categorise me with like-minded things.
- I can be quickly identified, and critical information associated with me.
- My performance can be assessed against all the others of my type.
- Use the Uniclass 2015 classification system here.

Function - I need to know what functionality I have because:

- It ensures that I meet the specific requirements at every stage of my lifecycle, even when nobody knows which piece of equipment or material will fulfil this.
- It helps to set my performance criteria for continued monitoring.
- This assists with the ISO 19650 UK Annex naming convention

Functional Grouping - I need to know what functionality grouping I belong to because:

- It associates me with those things that I interact with and work together to perform a joint functionality.
- This is also known as the asset breakdown structure
- It identifies other things that may be affected if I stop working.
- It helps to ensure I can be isolated, and the impact of my existence is understood.
- If this is an Element level asset tag this identifies the Functional Unit or the Primary Functional Unit, and so on up the asset breakdown structure.

Statutory Information – In legal terms what information is needed throughout the asset's lifecycle?

- This ensures I comply with any legal requirements
- This information will help in cases of disaster

Location - I need to know my location because:

- When I am being designed and constructed it is known where I will be placed.
- If something happens to things in the same location as me, the impact, even if not part of the same functional grouping can be assessed.
- It's the first question anyone asks, "Where is it?"

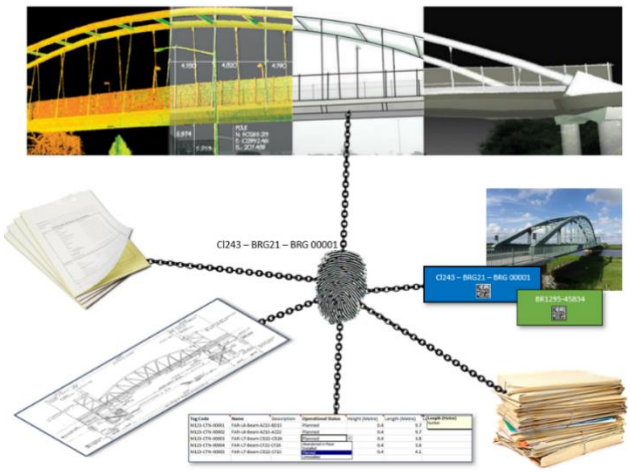
ID/Label - I need to how I will be identified because:

- When I am identified on any media (drawing, document, model, database etc) I need to be unique.
- When someone notices a problem in the physical world, I need to know they have correctly identified me.
- When the physical equipment that fulfils my function is replaced, it helps to ensure that we are talking about the same thing
- This is the identifier that will link all information relevant to me no matter what its source, location or format.

This information is built up over time throughout the lifecycle of the asset. The higher up the asset breakdown structure the earlier it can be collected. It can be used to better understand the security needs of the asset, the risk factor, its criticality and vulnerability in delivering the desired outcomes.

Labelling

In the virtual world giving our assets an ID or label will allow us to track and trace our them across multiple databases, throughout the entire lifecycle, as well as being the code that allows the instance of information relevant to that asset (and the systems its belongs to and impacts on) to be linked to other instances in other databases.



As soon as there is a function need identified, then an Asset Tag ID can be created, so that this function can be identified and traced throughout the lifecycle. As more detail is defined then more Tags will be created, and more IDs added to the asset register.

Every instance of this asset whether it is a drawing, 3D object, document, form, physical thing or related piece of information in a maintenance, HR, engineering, finance or asset register database will list this ID. So, when a search is done on something in the Digital Twin then all relevant pieces of information are taken into account.

The ID number can be whatever you want it to be, as long as it is unique to this asset tag. There are two polarised views on how we deal with this.

Firstly, that the tag should contain useful information about the asset and secondly that it should just be a unique ID that means nothing, because all the information is kept in the asset register/ database.

If you wish to put meaning into the ID, then I recommend the following:

Location– Functional grouping code – Classification – Unique numerical number.

This will allow you to understand how assets relate to each other and the function they play without needing to delve into the asset register/ database. It would be especially useful when physically labelling items in the set down area during construction and helping maintainers identify what they are looking at during operations.

However, there are security concerns here if they are used in public spaces, that could potentially allow criminal or terrorists to identify systems and vulnerabilities more easily.

Labelling during the lifecycle

As an example, we will look at the lifecycle of a major road scheme. The high-level outcome will have an ID number associated with the Critical Success Factors needed to measure it. That ID will be linked down to the Project Information Requirements.

The Outcome in this case is: *A road between A and B to reduce congestion by 55% in the town centre*.

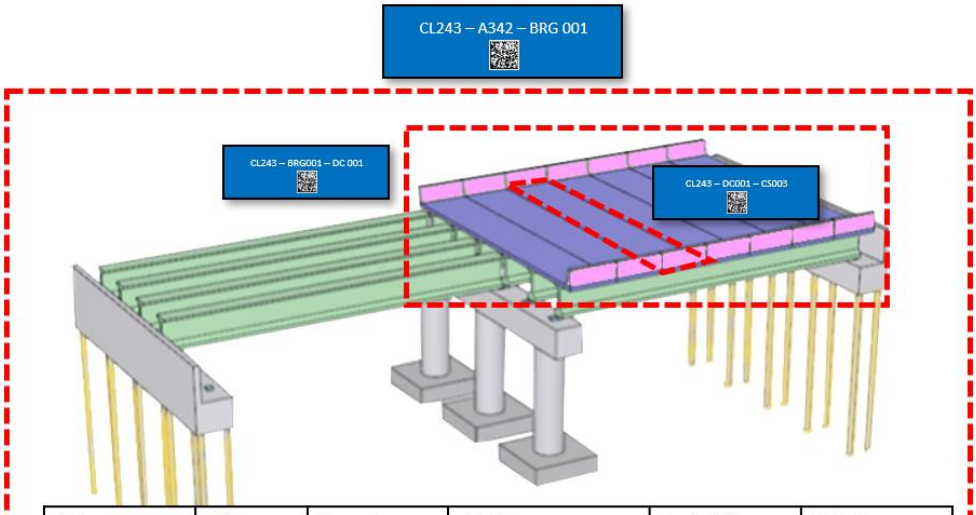
On looking at the geospatial information, it is clear that 1 dual-carriageway, 1 major junction, 4 bridges, 6 earthworks and 2 drainage systems are required. Each of these are Primary Functional Units making up the road Facility. Each one will have an Asset Tag created which will include an ID number.

In the CAD models, the documents, drawings and other databases this ID number is attached, so all instances of information relevant to this function are linked.

An asset register database should be started that will list these primary functional units alongside the basic asset tag information.

As we firm up that conceptual design, we can start adding functional units to the asset register building up a family tree of systems.

When the design becomes more detailed, each PFU and FU (see p. 27/28) will be broken down into individual elements, each will be listed in the asset register under their parent and labelled in the virtual world wherever they appear.



PFU	FU	Element	Label ID	Product S/N	Material
Bridge001			CL243-A342-BRG001		
	Decking001		CL243-BRG001-DC001		
		ConcreteSlab003	CL243-DC001-CS003		

As this structure is built up, information that will help to define the function and performance of the physical equipment, materials, product or service that will be procured when we get to construction.

During construction not everything will have a physical label, as it would not be cost effective to do this, so an analysis must be made as to what will have a label and what will not.

PFU	FU	Element	Label ID	Product S/N	Material
Bridge001			CL243-A342-BRG001		
	Decking001		CL243-BRG001-DC001		
		ConcreteSlab003	CL243-DC001-CS003	PCCS 01019	Precast Concrete

Having a physical label on the asset whilst commissioning, testing and handing over is a positive bonus in keeping track of what has been designed, procured, tested and is now going into operation.

This would support the “Golden Thread” principles set out in the Building a Safer Future report by Dame Judith Hackitt.

Asset Register

The asset tags at various levels have appeared in all the documents, drawings and models during this build up, but the most important place for them to be is in the asset register.

This register of assets needs to be accessible from every information creating, gathering and consuming system used in the PIM (Project Information Model), ensuring the “things” mentioned in all these sources of information are linked back to the relevant asset tag, this enables us to have all the information required to answer our critical questions throughout the lifecycle.

This asset register will not only contain information about the duty of an asset, but eventually it will include information on similar products which can fulfil that need, along with all the information about the physical thing.

My advice here is to never lock this register away in a CAD package (Whether a 2D drawing or 3D modelling system) and restrict its access to a small percentage of your team. Data is for databases so that it can be analysed, reported and linked rather than duplicated.

Temporary works

We need to treat our temporary works the same way we treat our permanent assets. I’m not suggesting that we tag every piece of scaffolding, but we are recommending that it is broken down into “supporting service” level, where each temporary works element supports a maintainable asset.

We should record these the same way in every drawing, document or model and ensure that they appear in the asset register to help answer any critical questions. Bear in mind that if they are abandoned in place, they will need to be handed over just like any other permanent asset.

Asset Information Requirements

Without doubt this can be the biggest task that you will carry out, if it is done properly, engaging all the end users of the information, throughout the lifecycle and ensuring that they get what is valuable to them.

Many of the end users will fiercely guard their information needs, as they may believe that without it, anyone else could do their job. They may leave out vital pieces either through accident, not thinking they are important or on purpose to ensure they, as a person remain important and irreplaceable in their organisation. You may also find that the length of time it takes them to find and verify a piece of information is looked on as bonus time out of the cold and wet of site. How you win them over in this cultural battle is a whole study in its own right!

To understand what is needed for an Asset Information Requirements package, we must start at the beginning and define what an asset is and how we put together an asset breakdown strategy.

What is an Asset?

According to ISO 55000, an asset is a thing, item or entity that has actual or potential value. This definition takes us away from thinking that an asset is just a physical thing and gets us to understand that it could include information, people and knowledge. The ISO also goes on to remind us that asset management is not about the management of assets but about delivering whole life, real business value. This is done by aligning everyone's understanding of value and risk, whilst balancing them both.


Bridge


Lock Gate


Pipeline

Junction


Ducting


Concrete slab


Pump


Light fitting

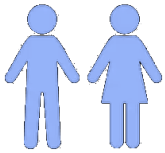

Wi-Fi signal

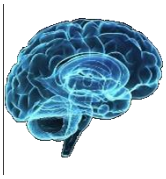

Wearing course


Rolling stock

Piece of data


Piece of data


People


Knowledge

All the examples above are assets in their own right, but many are groups of assets that form a functional grouping. As a rule of thumb, you should record assets down to the level you expect to maintain them; for example, a window is an asset, not the sealant, hinges or pane of glass but in reality, it will be down to the level that you as an organisation see value in.

When looking at these functional groupings they will be easily recognised as systems and sub systems that are brought together to form facilities and finally complexes when looked at from an asset breakdown perspective.

Asset Breakdown strategy

One of the key items on any digital journey for an owner should be to work out their asset breakdown strategy. This helps them to understand the links, dependencies and interdependencies of their assets. So, if one asset does not function as required whether through planned maintenance, breakdown, vandalism or natural disaster then the impacts on their other assets and the overall functions that support your business outcomes is understand. This impact study will define what urgency and resources are put into rectifying the issue.

It is also paramount to define your asset breakdown structure so that it forms the basis of how your CAD team set their modelling strategy.

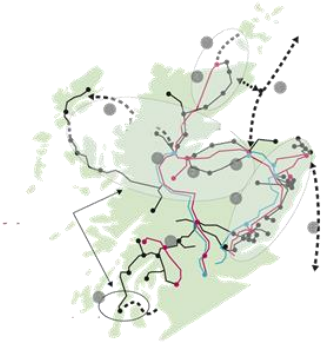
There are many different types of links and dependencies, the most common being the systems that the assets are part of. But others might be human, financial, political, maintenance, operational, environmental and functional to name a few. Each of which will take time and effort to map but will allow the owner to truly understand the impact of their asset on many levels.

If this is being done for a new asset then it can be a part of the design, but when it is existing, especially when its infrastructure related, then the following should be taken into account:

- It will be a system of systems
- It will not always obvious
- It can be buried and hidden
- It will be complex in their own right
- It will have evolved over time
- Ownership will have changed over time
- There will be multiple suppliers
- They will have been upgraded at some point
- Parts of it will have become obsolete
- They will be poorly recorded
- They will be recorded in different formats and on different systems
- They will be heavily dependent
- They will be interdependent
- They are all deeply connected
- They will not be isolated to one sector

Whatever the reason for creating the links and forming the breakdown structure, it should always be done with the end in mind, so talk to the people who will use this information and find out what is important to them before spending time and money creating it.

There is a generic hierarchy naming and explanation convention that will help.



Complex
The highest level, representing everything owned by the client

Facility
These are hubs or connectors in the strategic network.
i.e. Road, Junction, Station, Wastewater Treatment Plant, rail line, pipeline. In a Campus environment these are the buildings and the connecting links between them.

Primary Functional Unit (PFU)
The high-level functional systems within or along the facility, which may contain many different Functional Units
i.e. Gantry, Bridge, Earthwork, HVAC.

Functional Unit (FU)
The low-level functional systems that are part of the
Primary Function Unit

Element
Individual objects that carry out a distinct function. Depending on the detail required individual components could also be included. Beware of going down below the maintainable level!

The level you go down to will depend on the time and resources you have available.

Asset Level	
Complex	In Infrastructure this is the complete network encompassing all connected assets.
Facility	In infrastructure complexes these can be both Hubs and Connectors. For example, a facility could be a motorway junction or the road between them. A hospital, a reservoir, a railway line or a gas pipeline could all be labelled as a facility. • If you have a large network of assets start here and understand how they interact with each other and how dependent/ interdependent they are. • You can use CARVER analysis to work out your priorities for going down to the next level.
Primary Functional Unit (PFU)	These are the primary systems that make up a facility. On a motorway this could be a bridge, a gantry system or even an earthwork. • If there is limited time but you need to understand a specific hub or connector better due to its criticality, start here. • Understanding the PFUs is important during the preliminary design phase.
Functional Unit (FU)	These are the supporting systems inside the PFU. In a highways example these could be a speed camera system, the wearing course or traffic light system which is part of a bigger junction control signal PFU. • Once you have done the PFU and have additional time, progress onto here. • Understanding the FU's and the individual elements is essential in the detailed design phase
Element	This is the lowest level and is down to the level of value or in simple terms the maintainable level. • If you want to comprehensively understand your asset portfolio go down to this level, but not before doing the PFU and FU levels first. • Before you procure physical assets this level of asset breakdown structure is essential so that it is clearly understood how the physical assets will interact with each other in the system.

Levels of information needed

This breakdown structure also helps us during the lifecycle to define our levels of definition. If you imagine a new road project, at briefing phase, we know a new road **Facility** is required. We can create an identity for that level and start to hang information off of that instance. Moving into the concept phase, we now know that there is going to be a bridge **Primary Functional Unit** along that road, we can create an identity and build up further information that will impact the Facility.

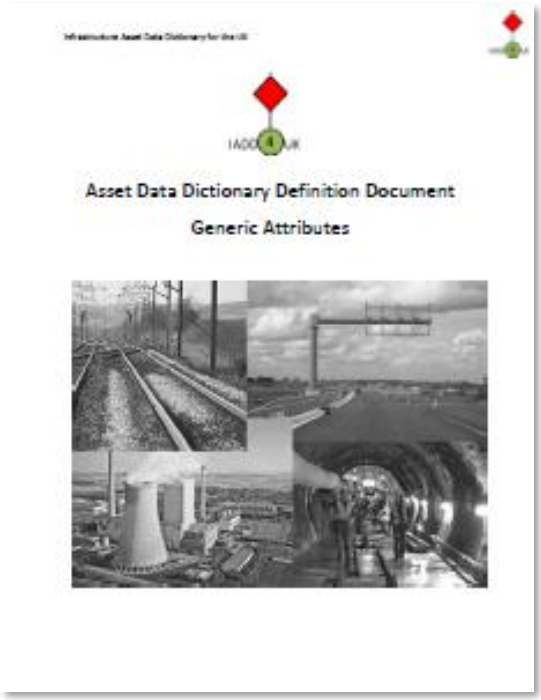
In the detailed design phase, we now can identify **Functional Units** and individual **Elements** that will make up the **PFU.** Once again allowing us to build more information that will have an impact all the way back up the asset breakdown structure.

Finally, when we get to construction, we can then talk to the manufacturers who will supply us with products that will be specified by the functional requirements at each level.

Writing your Asset Information Requirements (AIR)

Also known as an Asset Data Dictionary (ADD), the AIR package is a database that will define what information is needed at each stage of the lifecycle. When putting together your Exchange Information Requirements (EIR) document, it is important to specify which pieces of information will be supplied and which pieces are required to be handed over at the end.

Every type of Facility, Primary Functional Unit, Functional Unit and Element will have an entry against which the information requirements are set. When extracting from the ADD, a document (or report) is created and this will display in a simple manner all the details in something called an Asset Data Dictionary Definition Document or AD4 for short. This isn't really a document, but a report on the database, presented as a document so that a specific project role can easily understand what is required of them.



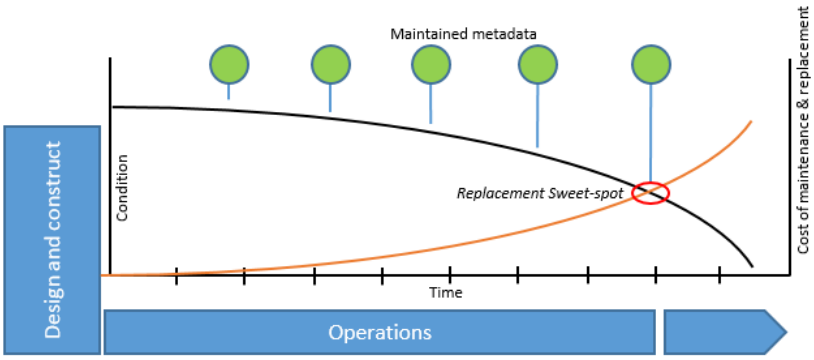
The AD4 does the following:

- Defines type of asset
- Sets the functions and classes that relate to them
- Defines the attributes specific to a role so they can deliver their required part of the digital asset and how they are to be presented (formats etc)
- Lists who is responsible, accountable, needs to be consulted or informed during the collection, curation and communication of this information.
- What an Attribute means e.g. Length/Depth etc
- Contains relevant diagrams or examples to clarify

When running the report to generate a role specific AD4, it is important that the detailed project **r**esponsibility/ **a**ccountability/ **c**onsulted and **i**nformed (RACI) matrix is used.

This Asset Data Dictionary or Asset Information Requirements package is informed primarily by the asset strategy put together through ISO 55000 and needs to be based on what is needed or valued by the various end users of the information. There are many different end users throughout the lifecycle and whilst this asset data dictionary ought to contain all of these requirements this would be a huge undertaking, so it is recommended to start with the areas that will give you the best value to your organisation.

Throughout this lifecycle information will be exchanged between various parties and this was described as a "data drop" and illustrated by a green "ball" in the various standards. The diagrams might be slightly misleading showing that an exchange of data is only done at the end of a lifecycle phase whereas it needs to be more of a dialogue that is exchanged when required to answer a question, make a decision or carry out an activity rather than just a ball to be lobed over the fence!



Strategy phase

At the beginning of the new projects lifecycle, a subset of the Organisational Information Requirements that are relevant or have an impact on this project will need to be taken into consideration so that the course of action taken, takes into account things like political will, social, environmental and economic impact when deciding what to do and how to define the new outcome. The AIR/ADD might refer to this if it is relevant to a specific asset.

Briefing phase

The AIR/ADD needs to set out what will be given to the delivery partners. This way a standard set of information is always handed over and it can be relied upon to be trustworthy. This should remove the uncertainty as to what will be received and the potential costs of re-surveying.

Concept

During the concept phase the consultant will deliver conceptual ideas of how they will fulfil the client's outcomes. There will be information that is important to the client and this needs to be defined in the AIR/ADD so that they can evaluate the different options delivered by the consultant depending on what is important to them. This concept will be made up of high-level functions that will fulfil the desired outcome.

Design

The design phase will take those high-level functions and break them down into a finer granularity of functional units. The AIR/ADD will need to define how these are best described so the client has confidence that the consultant is meeting their needs and the contractor will be able to procure or create a physical thing to fulfil it. Having a standard set of information requirements across multiple owners, as per the aspiration of the IADD4UK initiative, will also ensure that information generated in multiple places by multiple delivery partners is defined the same way, reducing the risks of interoperability issues.

Construction

Up until now the information build up has been focused around the functional requirements and the information to define, record, measure and monitor them. It is only now that we start to look at the products, materials or services that will fulfil this need. The information listed in the AIR/ADD here will need to reassure the client that whatever the contractor is planning will succeed in achieving their outcomes. When the products, materials or services are procured they will come with a product data sheet, that should answer the information needs specific to them listed in the AIR/ADD.

Commissioning

It is hoped that because there has been a constant dialogue of information exchanges between supply chain and client up until now, whatever has been designed and procured will meet the desired outcomes. This commissioning part of the AIR/ADD will define the information used to test both that the physical asset is fit for purpose and that the information package delivered with it is correct.

Operations

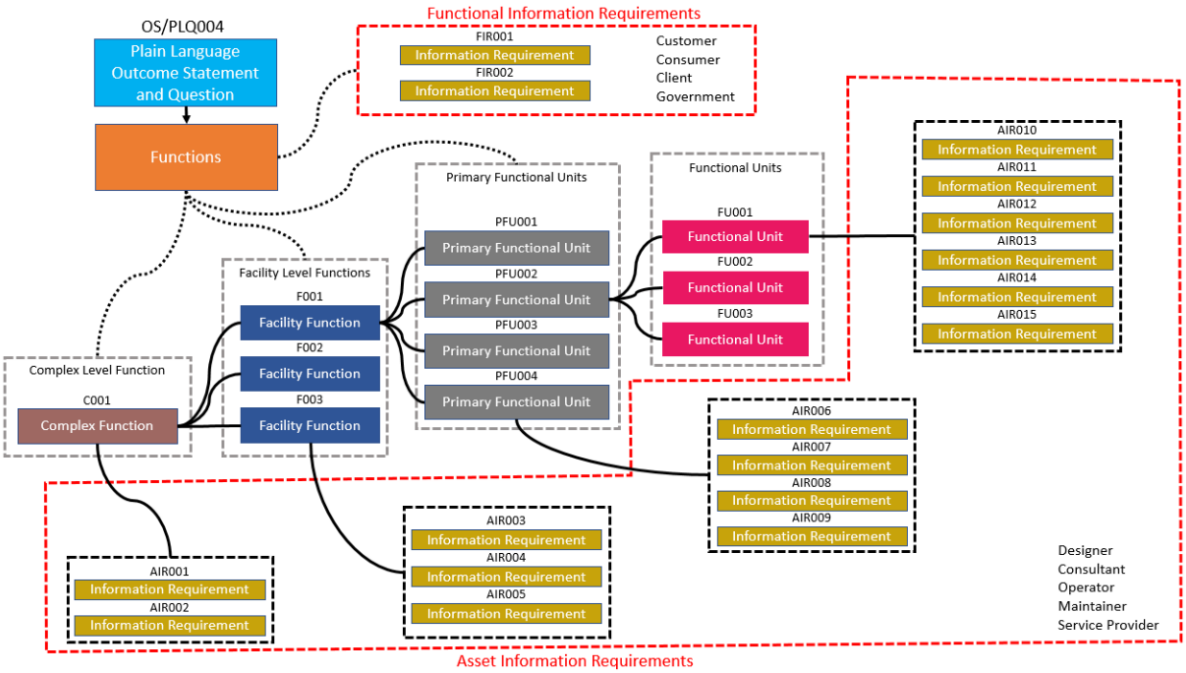
During everyday operations, information on the status, performance and usage of the asset needs to be gathered to ensure the Asset Information Model (AIM) is up to date. What this information is, needs to be defined and documented in the AIR/ADD. The AIM in turn will need to contain operational manuals, instructions and procedures to ensure the asset is run efficiently according to the outcomes of the organisation.

An interesting example of active feedback on status and performance came from a metro system in India. Many of the assets in the public areas had labels on them with a data matrix

code and the commuters all had an App on their phones for timetables, alerts and bookings. The App also had a reporting function that allowed the user to let the metro owners if there was a problem with the asset. Simply by scanning the data matrix code, taking a photo of the issues and adding some text, the owners could gather performance, function and customer satisfaction against their assets, greatly enhancing the feedback loop.

Maintenance

Effective and timely maintenance is key to ensuring a safe and healthy asset whilst delivering the end user the outcomes they expect. Understanding what information is required for maintenance will be difficult without getting on side the people who actually do the job. A maintenance manager will only be able to tell how to manage and schedule a maintenance regime, whilst the engineer who knows what needs to be done will closely guard that secret to ensure they are kept employed. A significant amount of time and money is wasted in this phase due to not having access to trusted information. Don't just think about data about the individual asset, but also how it will be accessed, the tools and PPE required, as well as the other assets physically or functionally effected when the asset is taken out of use for work to be carried out.



Disaster

This is the phase you hope never happens and frustratingly is little documented in the BIM or Digital Twin world. If there is a fire, flood, terrorist or other incident then having rapid information that can be given quickly to the attending response team, can mean the difference between life and death.

The end user in these scenarios will be the police, fire, ambulance or national security teams that will limit the impact of an incident. They need to be engaged to define in the AIR/ADD what information they will need and how they need to consume it. I came across a great example in China recently where all the latest disaster information was synchronised into a tablet device, so it could be handed over to the incident controller when that emergency team arrived.

Decommissioning

During decommissioning the contractor will need to understand any resale, recycle or reuse targets and follow specific instructions on ensuring assets are disposed of responsibly. This information will impact on the design and build phases, educating the consultant and contractor as to what is the priority.

Defining the data at each of these stages or *data drops* should be done by the relevant people asking the critical questions.

Having a comprehensive Asset Data Dictionary with its metadata definitions for each asset down to the maintainable level will deliver significant benefits to the client at every stage of the asset. However, if this is delivered on a nationwide level, giving a standard across the board to road, rail, power, water, prisons, hospitals and schools, we find that delivering our asset information will become more cost efficient, as contractors and owners talk a common information language. This also has a wider benefit of driving interoperability between technologies, as they will all begin to describe their objects in a common and interchangeable way.

Strategy for creating an AIR/ADD

Without significant investment of time, resources and money a fully comprehensive AIR/ADD and its metadata will be difficult to achieve. So, an initial strategy called "*Critical Questions*" is used to help create our first iteration.

Critical Questions requires the AIR/ADD author to engage with a group of metadata users for each task in each discipline at each of the data drops that will be covered. These users will be asked to write down the critical questions they would ask in relation to a specific asset. Once analysed these questions will lead directly to the metadata needed to answer them. Using this methodology, we can gather significant amounts of critical metadata requirements for our AIR/ADD. Like with our OIR, the relationships between the information requirements and the related questions needs to be kept so that this can be used later to track if we are successful and also to assist with role-based information sets. It is also useful to record how that information needs to be presented, whether in document, metadata, drawing or some other method.

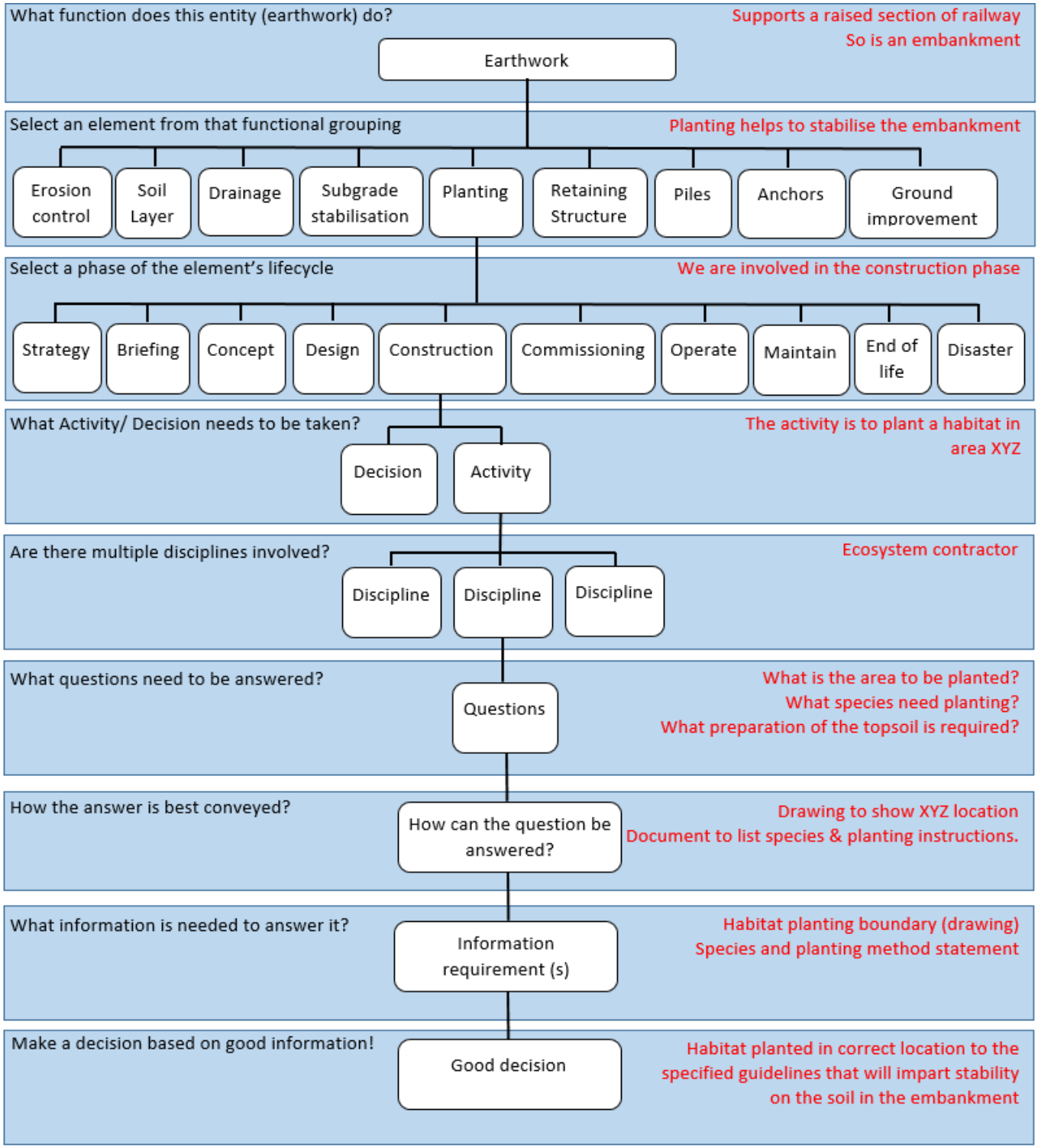
The key with the Critical Questions method, as it should be with all AIR/ADD definition methods is to **TALK TO THE PEOPLE THAT ACTUALLY NEED THE INFORMATION**, not their manager or a committee of academics or well-meaning industry institutes or people.

There will also be a difference between what they *need* and what they *want.* It will be important for the author of the AIR/ADD will have to make the differentiation between the two.

The next step is to define the replacement criteria and required performance/ functionality. This information combined with ongoing condition and performance surveys will help to determine the degradation of the asset and with good analysis, will predict when the asset needs replacing.

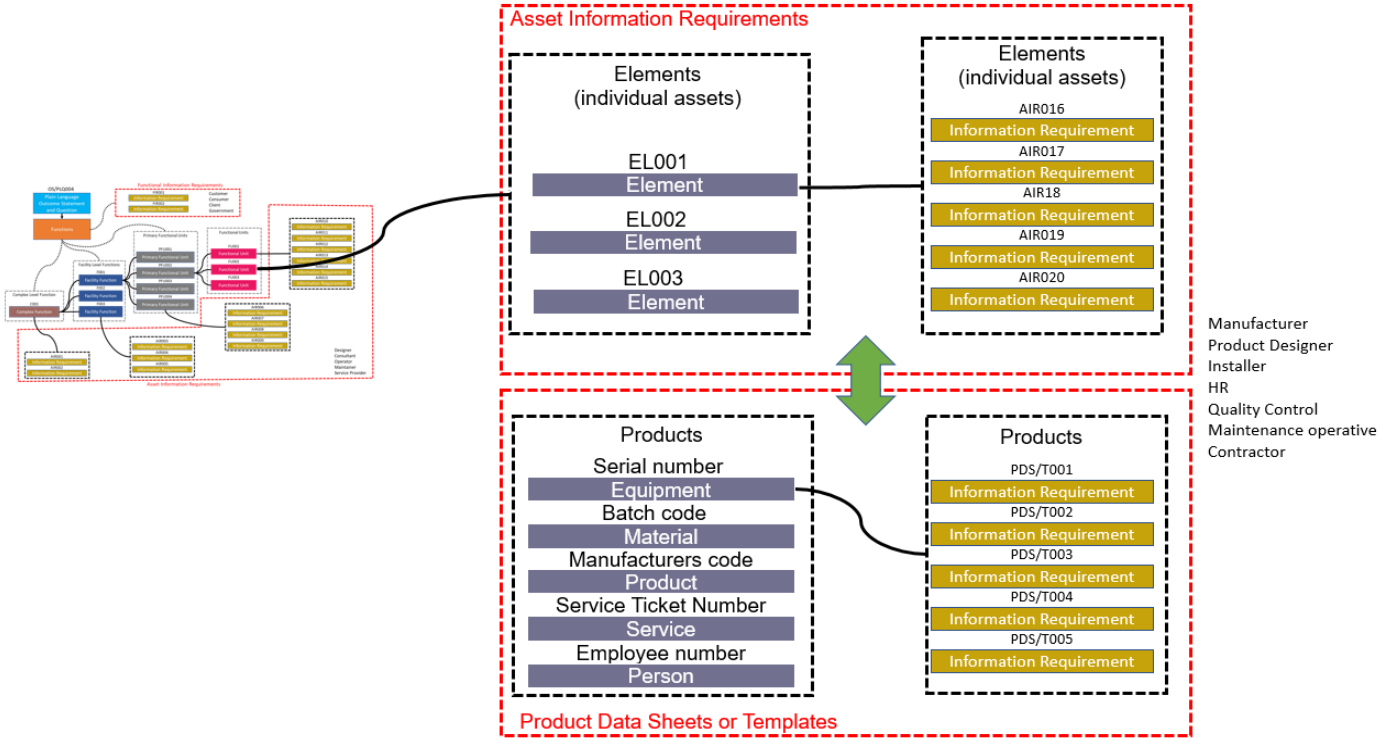
Between these steps we should be able to collect at least 80% of all the information required across the lifespan of our assets.

In the example below we will use a humble, yet complex earthwork to show how this might be accomplished.



The way the information could be presented, will need to be looked at, as the end user you are engaging might not be aware of other methods such as virtual reality, video or some other method that will convey their requirements in a quicker, easier to understand or cheaper method.

A common Asset Data Dictionary or Asset Information Requirements package between all infrastructure owners will not only assist the delivery partners and the owners reduce costs, but also help product manufacturers and supply chains understand what information is valuable to their customer. Each of the individual element pieces of information will define what product is required through function and performance data and will also define what they need to provide in their product data sheets or templates.



Human vs automated collection of information

How these pieces of information are collected or continuously monitored will depend on their value, the frequency required, the speed of any intervention or reaction required and also how much it cost.

Whilst researching and authoring the AIR/ADD it is important to understand these factors, so that a recommended course of action can be set out.

It may appear at first that humans are a cheap way of collecting information, but the time taken to locate what is to be recorded, write it down and then bring it back to wherever it needs to be entered into a system is not only time consuming, but also contains the “human factor” risk of incorrectly read, noted down or keyed in data.

Sensors are cheap, data storage is even cheaper. If something can be collected in an automated fashion, then it is recommended to do so. However, bear this in mind: the sensor has no become another asset that will require some form of maintenance, calibration and inspection!

The way they transmit information and whether they can be jammed or spoofed for criminal or terrorist activity must also be taken into consideration.

Wrapping up the IADD4UK organisation

In 2018 it was decided to wrap up the IADD4UK organisation through lack of investment and funding from either government or client organisations. The work it completed and the lessons that were learnt have a great value, hence this legacy document.

It was fully recognised, that to complete a comprehensive cross sector infrastructure asset data dictionary that defined all the information requirements throughout the lifecycle of any asset is a truly herculean task. This guide defines the methods that can be used to do so and also some of the ways to make it an easier pill to swallow and finance.

IADD4UK would like to thank the following organisations for contributing to the meetings, workshops and trials.

- Transport for London
- Network Rail
- Highways England
- Crossrail
- MOD
- Costain
- Atkins
- Tubelines
- Balfour Beatty
- Fluor
- BAM Nuttall
- Clugston
- DPA
- Transport Scotland
- Interserve
- Bentley Systems UK
- COMIT
- Speedy Hire
- Temporary Works Forum
- EDF Energy
- Enable my Team
- AEC3
- Water Research Centre
- Tideway Tunnels
- Bechtel
- Mace
- Keller
- Intra-TeamIT
- Institute of Highways Engineers
- Environment Agency
- Turner Townsend

Thank you to Jarosław Szczepanek for his editing and also to our two chairman Ross Dentten and Iain Miskimmin, and the hard work of Dejan Papic, Michal Zu and Adam Young.