Co-funded by the
Erasmus+ Programme
of the European Union

Continuing V.E.T. Training Programme in Lean Construction

Aveiro/Porto, 10 july 2017

ERASMUS+ Programme
Key Action 3 | Call 2016
Support for Policy Reform
Support for small and medium sized enterprises engaging in apprenticeships

Project Code:
2016-1-ES01-KA202-025694

Partnership:

- Fundación Laboral de la Construcción (Spain).
- Asociación de Constructores y Promotores de Navarra (Spain).
- Tipee (France).
- Sustainable Habitat Cluster (Portugal).
- Warsaw University of Technology, Civil Engineering Faculty (Poland).

INDEX

2. IPD - INTEGRATED PROJECT DELIVERY

2.1 Introduction

The AECOO industry faces nowadays big challenges (Construction 2030, 2015) (WEF, 2016). By being a structural part of countries economy, this sector performance can influence a more or less favourable scenario for growth. The performance indicators of Construction are geared for a complex net of areas, such as environment, competitiveness and sustainability (EC Strategy, 2012). The lack of innovation in general construction processes (McKinsey, 2016), the cost and time overruns (KPMG/PMI, 2013) (Pramen, 2013) as well as the growth of other industrial sectors with improved communication for the society, relegated the sector to a secondary role.

It is common to see written that construction lost its role on industrial leadership (Wolstenholme, 2009). This sentence might be true, but there are very interesting case studies where construction is on the top of the technological innovation. These are some, but still few on the overall picture.

It is necessary to leverage the industry raising the bar on its requirements and outputs. Perform better, with improved processes, achieving better results, but without reinventing the wheel!

With these strong words it is meant to say that, changes are needed and on the other hand, there are processes that can/need/should to be maintained or readjusted. All the past processes of the industry are not necessarily old-fashioned and incompatible with the trends (Lou, 2017).

The industry has a lot of knowledge and potential but has shown inability to set its way on the tracks and now it sounds a bit lost and flooded with buzzwords that more than "fashions" are loose ingredients for the common driver that is achieving an improved industry at all levels (Eilif, 2017).

These notes have the scope of providing background tools/documents and demystify the roadmap to an improved industry based on IPD – Integrated Project Delivery, and namely the major components that "compose it".

IPD is still in its infancy (AIA, 2014) and therefore is still a work in process where continuous updated will be made, namely in what regards agreements and type of procedure. Following this vision, IPD is becoming a procedure in order to assure the correct assemble and increased result of all its parts/agents/major components.

Yet, from the point of view of this training program it is important to recognize the main components of IPD, namely those that are well known due to their impacts/problems for the supply chain and have taking place for many years. Solving one issue or assuming one component will not transform a project on an IPD one. Yet, it will certainly improve some overall results.

IPD is therefore presented as a global framework, assuming a sum of major components that need to be understood and adopted, as well as following its way becoming a specific type of procedure for the industry to adopt.

2.2 Terms and definitions

AECOO – architects, engineers, contractors, operators and owners;

Stage/phase – division of a standardized process map for the acquisition of a facility, at some of which the requirements can be delivered (PAS 1192-2:2013);

Owner – individual or organization owning or procuring an asset/facility (BS 8536-1:2015);

Designer – person or organization responsible for stating the form and specification of a building or parts of a building (ISO 15686-1);

Contractor – person or organization that undertakes construction work (ISO 15686-1);

Project – unique process, consisting of a set of coordinated and controlled activities (3.1) with start and finish dates, undertaken to achieve an objective conforming to specific requirements, including the constraints of time, cost and resources (ISO 9000);

Built object – physical construction result (3.4.6) intended to serve a function or user activity (adapted from ISO 12006-2:2015);

Facility – collection of assets which is built, installed or established to serve an entity's needs (ISO/DIS 18480-1);

BIM – Building (construction) Information Model – shared digital representation of physical and functional characteristics of any built object, including buildings, bridges, roads, process plant. It may form the common basis for decisions and may form the contractual point of reference, across one or more stages in the life cycle. (Definition combined with ISO 29481-1 and ISO/TS 12911);

AIA – American Institute of Architects;

Life cycle – consecutive and interlinked stages of the object under consideration; stages and activities spanning the life of the system from the definition of its requirements to the termination of its use, covering its conception, development, operation, maintenance support and disposal (ISO 15685-5:2008 and adapted from ISO 14040 combined with IEC 61508 and ISO/IEC 15288:2008 and ISO/TR 18529);

Project life cycle - defined set of stages from the start to the end of the project/construction process (ISO 21500 and ISO 12006-2);

Agent/actor/stakeholder/participant – person or organization or an organizational unit (such as a department, team, etc.) that can affect, be affected by, or perceive themselves to be affected by any aspect of the project/construction process (definition combined with ISO 21500 and ISO 29481-1);

Project team – person or organization involved on the process of delivering a built object/facility;

Design team – person or organization responsible for stating the form and specification of a building or parts of a building (ISO 15686-1);

Operator – organization responsible for the day-to-day operation of an asset/facility (BS 8536-1:2015);

Client – person or organization that requires a building to be provided, altered or extended and is responsible for initiating and approving the brief (ISO 15686-1);

Users – person, organization or animal for which a building is designed (including building owner, manager and occupants) (ISO 15686-1);

Procurement – activity of acquiring goods (3.7) or services (3.23) from suppliers (3.30). The procurement process considers the whole cycle from identification of needs through to the end of a services contract or the end of the life of goods, including disposal. Sourcing is a part of the procurement process that includes planning, defining specifications (3.26) and selecting suppliers. (ISO 20400:217);

Procedure – is a structured way of performing procurement to consult the market for the purchase of these goods and services. A procurement procedure leads to the conclusion of a public contract (Eurojust).

RIBA – Royal Institute of British Architects;

2.3 Principles of IPD

2.3.1 IPD Definition

The most known and recognized definition of Integrated Project Delivery (IPD) is presented by the American Institute of Architects (AIA, 2007) on the 1st version of the Integrated Project Delivery: A Guide. In this document it is stated that:

> "Integrated Project Delivery is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases (stages) of design, fabrication and construction. **Integrated Project Delivery principles can be applied to a variety of contractual arrangements** and Integrated Project Delivery teams will usually include members well beyond the basic triad of owner, designer and contractor. At a minimum, though, an integrated project includes tight collaboration between the owner, architect/engineers, and

> builders/contractors ultimately responsible for construction of the project/built object, from early design through project handover." (AIA, 2007)

In essence, the principles of IPD at that time did not involve (or it was assumed as optional) the technological part. In addition IPD was envisaged as an approach that could fit on different types of procedures. Other publication, dated from 2013, confirms this trend and assumes that if technology is to be embedded on the principles, then the IPD term would be changed to IDDS – Integrated Design & Delivery Solutions (CIB_Pub.370, 2013).

Notwithstanding, the trends towards digitalization (McKinsey, 2016) and the introduction of methodologies supported by technology/digital solutions, namely Building Information Model - BIM, prove to contribute for IPD achievement. In practice, BIM is an integral facilitating mechanism for IPD projects. (CIB_Pub.370, 2013)

Given the evolution of the industry, its challenges and trends, the AIA recognized that the initial document could benefit by refreshing the definition and principles based on experience and implementation of actual Integrated Project Delivery projects.

Presently, the updated definition of IPD is published on the document "Integrated Project Delivery: An updated working definition, version 3" (AIA, 2014) and it is the following:

> **Integrated Project Delivery (IPD)** is a project delivery method that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases (stages) of design, fabrication and construction. The Integrated Project Delivery method contains, at a minimum, all of the following elements:
>
> - Continuous involvement of owner and key designers and builders/contractors from early design through project completion;
> - Business interests aligned through shared risk/reward, including financial gain at risk that is dependent upon project outcomes;
> - Joint project control by owner and key designers and builders/contractors;
> - A multi-party agreement or equal interlocking agreements;
> - Limited liability among owner and key designers and builders/contractors;

One aspect that is highlighted from this document is the awareness of the requirements in order for a project to be considered IPD:

> **"Projects using incomplete models of integration, often called "IPD-ish," have caused much confusion in the industry."**

Given this, it is assumed that in order for a project to be identified as IPD, there are some major components or “ingredients” that need to be observed, otherwise it should not be assumed as such.

Given the importance of these components and their individual benefits for the process, they will be explored step by step to identify benefits and difficulties on the adoption.

At the same time, it is found essential to understand the evolution of the term since the beginning of 2005. As mentioned, IPD is composed by several major components that play an essential role for the global achievement/accomplishment/expected result.

From 2005, several entities have worked on the IPD method in order to identify the main ingredients and the essential parts that make a project IPD or not. As it will be presented, in terms of main aspects there are some differences between the logic of the main pillars for IPD and main principles, revealing also the continuous development and update of the term.

The following points will present the particular visions and combine them all together for the materialization of the present major components of IPD.

2.3.2 The Seven Pillars of Integrated Project Delivery

The International Council for Research and Innovation in Building and Construction – CIB, has developed a Research Roadmap Report “Integrated Design & Delivery Solutions (IDDS)” (CIB_Pub.370, 2013) that presents an understanding on the main components of IPD. This document was developed to provide guidance for future developments and alignment with essential aspects to consider when doing research on the Project Management topic. The vision of IDDS is to “minimise all forms of waste, whilst delivering greater assured value for sustainable whole life cycle outcomes”.

For the purpose of an IPD project it is assumed that BIM is, in theory, optional. IDDS gathers IPD and the technological part, meaning that if it is assumed that IPD integrates technology, IPD and IDDS can be found the same in terms of main principles and components. Note that IDDS does not set a default procedure as it is a trend with IPD.

For the purpose of the IDDS research roadmap IPD is composed by seven pillars as presented on Figure 1.

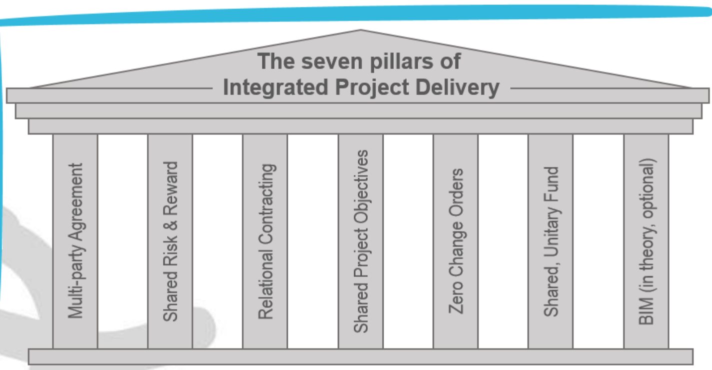


Figure 1. The Seven Pillars of IPD. After Spata (2010) (CIB_Pub.370, 2013)

2.3.3 The Principles of Integrated Project Delivery

From a slightly different perspective, the AIA (AIA, 2007_2) defines the main principles towards IPD as it follows:

- **Mutual respect:** In an integrated project, owner, architect, consultants, contractor, subcontractors and suppliers understand the value of collaboration and are committed to working as a team in the best interests of the project. To harness the collective capabilities of the integrated team, all key participants should be involved as early as possible with multiple disciplines and interests/goals represented. Roles are not restrictively defined, but assigned on a “best person” basis;
- **Mutual Benefit:** All members/agents will benefit from integrated project delivery. Because the integrated process assumes early involvement by more parties, the compensation structure must recognize and reward early involvement. Compensation should be based on the valued added by an organization and risk should be equitably allocated. Integrated projects will use innovative business models to support, rather than discourage, collaboration and efficiency;
- **Early Goal Definition:** Project goals are developed early and agreed upon by all participants (definition and ownership). Insight of each participant is valued in a culture that promotes and drives innovation and outstanding performance. True value engineering is obtained by collaborative focus on the project goals, including system performance throughout the facility life cycle;
- **Enhanced Communication:** Focus on team performance is based on communication among all participants that is open, straight and honest. Responsibilities are clearly defined in a no-blame culture leading to identification and resolution of problems, not determination of liability;

- **Clearly Defined Open Standards:** Open and interoperable data exchanges based on a disciplined and transparent data structure is essential to support integrated project delivery. Enhanced communications between all participants is made possible with open standards. All technologies used on an integrated project should use open standards to eliminate the costly practice of integrating every application (and version) with every other application (and version). Interoperability exists on the human level through transparent business exchanges, supporting these exchanges with open standards completes the goals of integrated project delivery;
- **Appropriate Technology:** Integrated projects will often rely on cutting edge technologies. Technologies should be specified at project initiation, to maximize functionality, generality and interoperability;
- **High Performance:** Integrated projects will lead to optimized design solutions, higher performance buildings, and sustainable design;
- **Leadership:** Although each participant is committed to achieving project goals, leadership should be taken by the person or organization most capable with regard to specific work and services. Often, the design professionals and contractors;

2.3.4 Present Framework

As mentioned, the experience from IPD practice, the construction industry strategic trends (environment, sustainability, competitiveness) and requirements in terms of practices update and digitalization, contribute to the revision and update of the IPD definition and its major components or “ingredients”. At the same time, the need to draw a visible line between what is an IPD project and projects that embed parts of its components is also an important issue. Therefore, and using all the evolutions from 2005 until nowadays it is possible to present the following IPD principles (Figure 2).

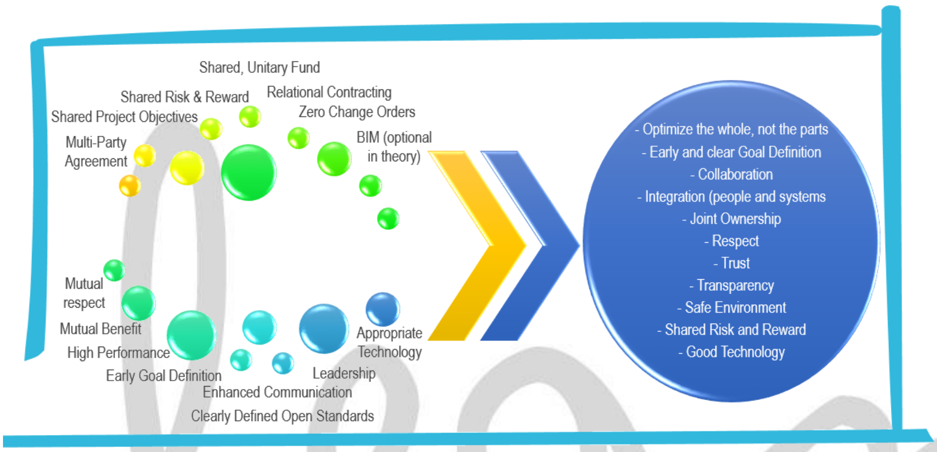


Figure 2.

Pillars, Principles and Present principles Framework

- **Optimize the Whole, not the parts:** The point of **integrating the project team** is to deliver the whole project in a way that gives owners what they value. Whether that is optimized design solutions, increased efficiency over the building's lifetime **(integrated systems)**, or a fast track schedule, higher performance requires that all parties make decisions that are best for the project, rather than their own slices of the pie **(High-performing Building)**;
- **Early and Clear Goal Definition:** In order to optimize the whole, the team must agree on what the "whole" is. Project goals are developed early and agreed upon by all participants/agents (goals definition and ownership). Project budget is set early and the team designs to the price, rather than pricing a design **(process integration)**;
- **Collaboration:** In order to optimize the whole, the **project team must collaborate** closely, deeply, and continuously;
- **Integration (people and systems):** People can't collaborate unless they can easily share **information**, find appropriate times and spaces to communicate, understand how their different design processes interact, get their billing departments to work in harmony, and get many other **systems integrated** (big and small) together across company lines;

  At this level, when addressing to integrated systems there are two possible visions; one from the technology point of view, where a system is a software or technology and the driver is interoperability, and system as a part of a construction object (water pipping systems), where the driver is the harmonization, compatibility and coordination of solutions. On IPD and on these notes, when addressing to integrated systems, as it will be further explored, it is meant to applicate the second vision.
- **Joint Ownership:** Meaningful **collaboration** requires participants to have a sense of ownership over the project and end goals;
- **Respect:** **Collaboration** also requires respect. The project team mutually commits to treating each other with respect and valuing each professional's input. Innovative solutions can come from any team member, so roles are not as strictly defined as on traditional projects, but rather assigned to the best qualified person;
- **Trust:** Meaningful collaboration cannot occur without trust. Trust is fostered through experience together, as well as purposeful decisions;
- **Transparency:** Trust requires transparency. **Communication** among the team is not limited to traditional silos or top-down distribution. Information of all types, from design rationale to BIM lives in a central location so all team members have access to accurate and current **information**. Often an investment in technology compatibility (interoperability or "good technology"; or the first vision previously presented) will be necessary to

ensure that all team members have access to the information they need to coordinate;

- **Safe Environment:** Trust also requires a project environment in which team members are safe to experiment and suggest innovations without fear of being wrong;
- **Shared Risk and Reward:** An integrated project depends on **best-for-project decision-making**. However, it is very rare that a firm will actually sacrifice its own profitability for the good of a project. Under IPD, **risk/reward sharing (measurable value)** structures are set up to cost or benefit the participants/agents according to project outcomes rather than individual firm contributions. This aligns the decision-making influences – a decision that is best for the project will benefit all participants, one that attempts to benefit one firm at the expense of the project will reduce profitability for all participants;
- **Good Technology:** **Integrating systems** (as to the first vision) together across company lines becomes much easier when using good technology. For projects requiring high levels of integration, technology like BIM, cloud servers, teleconference tools, and others become crucial to making it all work. It is important to factor in the investments in both money and time to get these up and running smoothly **(visualization/simulation)**;

A simplified approach and organized on a step by step chart can also be drawn, as presented by Fischer (Fischer, 2017). This simplified framework transforms the previous presented principles, setting steps towards IPD adoption. As it is possible to observe, the terms set on Figure 3 are present on the principles description; see the coloured words.

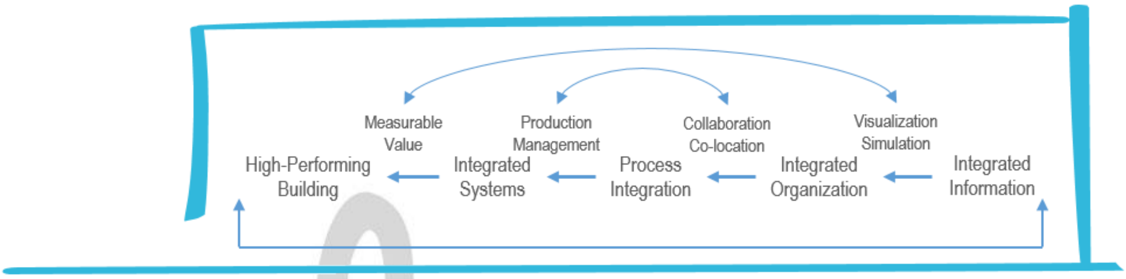


Figure 3. A simple framework for integrating project delivery (Fischer, 2017).

2.3.5 Highlights

It is based on the framework from Figure 3 that the major components of IPD will be explored on the following points. At the end, it is meant to be clear the requirements in order to deliver an IPD project as well as guidelines for measuring the overall guidelines.

It is important to underline that IPD is made of several components that can be worked separately and provide specific positive aspects for the projects but the trends are pointing to IPD as a procedure with specific agreements/contracts setting specific rules for the measurement and achievement of project outcomes.

One essential aspect that will be explored in point 2.6.3 is the commitment of the owner with the process as this agent has a major role on the global endeavor, as well as common resistances from the several agents with the process.

2.4 Project Stages

2.4.1 Introduction

A project is a unique set of processes/stages consisting of coordinated and controlled activities with start and finish dates, undertaken to achieve an objective. The achievement of the project objective demands deliverables conforming to specific requirements, including multiple constraints such as time, cost and resources (ISO 21500, 2012). At this level, construction is no different from other industries and therefore the same global framework is applicable.

Traditional projects follow a rigid sequence of stages. There are several guidelines and recent developments at this level that are very important in order to frame the activities and relations of the agents during the construction process when facing different types of procedures.

This part starts with a global framework for Project Management, setting the specific way for the singularities of the construction industry. Main stages, relations with the procedures, main activities/tasks, documents and relation between agents is explored.

Following, the IPD requirements will be presented and framed with an integrated construction stages matrix that is found to be a good generic approach for the achievement of several goals towards IPD.

This point, and following the simplified framework, presents and explores ways towards **Process Integration** and **Integrated Information**.

2.4.2 Project Management

Project management is the application of methods, tools, techniques and competencies to a project. Project management includes the integration of the various stages of the project life cycle. Project management is accomplished through processes. The processes selected for use in a project should be aligned in a systemic view.

The ISO 21500:2012 standard provides Guidance for project management, defining high-level description of concepts and processes that are considered to form good practice in project management. It is meant to be generic and a framework for detailed and specific developments for different situations.

Although many projects may be similar, each project is unique as differences may occur on the deliverables provided by the project; the stakeholders (clients/users) influencing the project; the resources used; and the way processes are adapted to create the deliverables (ISO 21500, 2012).

Every project has a definite start and end/life cycle. As previously mentioned, a project follows stages. The general stages defined in ISO 21500 are the following presented in Figure 4:

Figure 4. Project general stages (based on ISO 21500, 2012)

Each stage of the project life cycle has deliverables. These are regularly reviewed during the project to meet the requirements of the sponsor/owner, customer/client and other stakeholders.

2.4.3 Construction Project stages

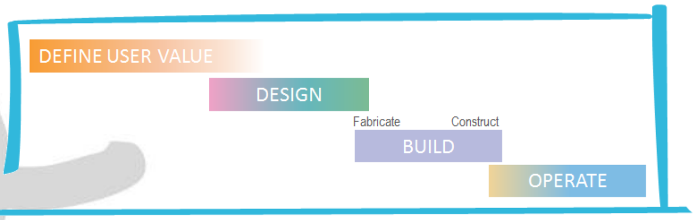
As stated, the AECOO supply chain (construction project life cycle or construction process) that leads to the built object/facility is no different from the generic approach presented.

In terms of project life cycle for the construction industry, two approaches can be drawn. There is a vision of the project or construction process that develops from the idea and definition/conceptualization until the end of construction, and other vision that starts on the same point and has development until the end of operation, including or not the end of life and possible scenarios (deconstruction, recommissioning, etc.). This definition is important as influences the overall process as well as the deliverables and measurements.

There are no mandatory references in terms of construction project stages, as these can vary according with the type of project, type of procedure, among other factors. For this purpose, several references will be mentioned, explored and harmonized. There are, however, peaceful divisions and guidelines that given their history, usability, among other, are recognized and widely adopted.

In terms of major divisions, there is always an initial stage where the objectives are drawn. Follows a stage where the object is detailed and specified; the design. With the end of the design follows the construction stage. Then the built object is delivered and starts to be used. Different interconnections might occur, depending on the type of project, object being built, procedure, among others.

Figure 5. Construction Project major stages, adapted from (Fischer, 2017)



2.4.4 RIBA Plan of Work

One of the most known and accepted guidelines for construction project stages in Europe is the RIBA Plan of Work (Sousa, 2008). Published for the first time in 1963, aimed the systematization of activities for building design teams during this specific stage. Set on a matrix form, it comprehended 12 tasks. Several updates were produced to extend the scope. Due to its wide adoption, all the developments since the end of the 90's aimed the integration and compatibility with other similar instruments and to fit on other types of works. The 1998 and 2007 versions evidence this effort (PoW, 2013). The 2013 version sets a new evolution on the history of this document. Aspects such as project life cycle, adequacy to different types of works and procedures, including IPD, and readiness for digitalization constitute main innovations.

The RIBA Plan of Work 2013 (PoW, 2013_2) provides a shared framework for design and construction that offers both a process map and a management tool. Whilst it has never been clear that architects actually follow the detail of the plan in their day to day activities, the work stages have been used as a means of designating stage payments and identifying team member's responsibilities when assessing insurance liabilities and they commonly appear in contracts and appointment documents (CIB_TG90, 2017). Given this testimony, the stages framework, its main objectives, support activities and main outputs will be presented. These can be used for different types of procedures and their scope might vary according with it (Procurement Bar). In terms of IPD major components, the follow up of these stages constitutes a first step towards **Process Integration**.

2.4.4.1 Strategic Definition

The core objective of this stage is to identify the Owner Business Case and Strategic Brief, as well as other core project requirements (PoW, 2013_2).

Among the key tasks to develop during this stage is the revision/feedback of the information from previous projects.

In terms of information outputs, the Strategic Brief is the main document to be established by the time of stage completion.

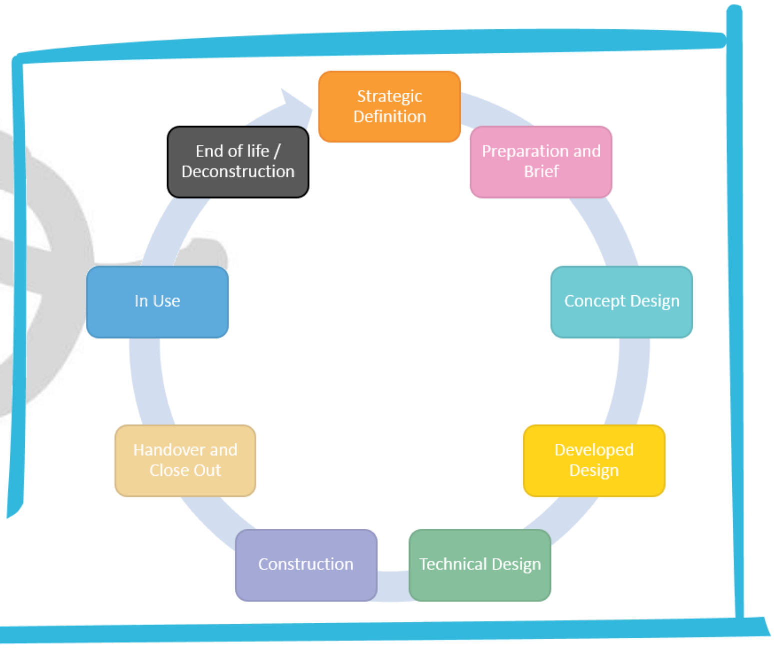


Figure 6. RIBA Plan of Work 2013 Project Stages (PoW, 2013_2)

2.4.4.2 Preparation and Brief

For this stage the core objectives are the development of the Project Objectives/Goals, including Quality Objectives and Project Outcomes, Sustainability Aspirations, Project Budget, identify other parameters or constrains and develop the Initial Project Brief. At this point it is essential the development of Feasibility Studies, review the information related with site and start the definition of measurement metrics.

In terms of key tasks it is essential to prepare the Handover Strategy and Risk Assessments.

In what regards information outputs, the Initial Project Brief is the main document to be delivered when the completion of this stage.

2.4.4.3 Concept Design

The mains tasks to develop at this stage is the preparation of the Concept Design that must include outline proposals for structural system design, building services systems, outline specifications and preliminary cost information along with relevant Project Strategies following the Design Program. Final Project Brief should be validated and issued.

From the support tasks point of view, initial reflections towards the preparation of Sustainability, Maintenance and Operation Strategies should be performed. The revision and update of the Project Execution Plan shall be made. Initial considerations regarding construction strategy, including offsite fabrication and the development of the Health and Safety Strategy.

In terms of information outputs, the Concept Design with the previous mentioned elements, the Preliminary Cost Information and the Final Project Brief constitute the key deliverables at the time of stage completion.

2.4.4.4 Developed Design

In some types of projects, some of the stages related with the design can be suppressed. Usually, this stage is the one chosen. The requirements can be anticipated or passed forward to the following stage.

When part of a project, its core objectives are the preparation of the Develop Design process that updates and details the contents of the Concept Design.

From the information output point of view, at the moment of stage completion it must be delivered the Develop Design, in which is essential to have more detailed information and an improved Cost Information.

2.4.4.5 Technical Design

On traditional project procedures this stage is essential as it constitutes the end of the design process and it is where all the information must be gathered and coordinated in order to be delivered to the contractor. On other types of procedures other agents besides the design team can be already involved. Notwithstanding, in terms of information detail and requirements, the goals are the same. This stage is where the design assumes the high level of information. The Technical Design includes the information from all involved disciplines, from architecture to structural and services engineering.

At this point and in terms of support tasks, the revision and update of all the previous mentioned documents must be developed, such as Sustainability, Maintenance and Operation, Handover, Health and Safety Strategies, revision and update of the Project Execution Plan and revision of the Construction Strategy.

2.4.4.6 Construction

The core objectives of this stage are the offsite manufacturing and onsite construction in accordance with the Construction Programme and resolution of Design Queries from site as they arise.

In terms of support tasks, they are now focused on the control of the construction, on health and safety on site and ensuring that the project handover and post-occupancy activities, determined earlier, are properly facilitated. This includes the revision and update of the Sustainability Strategy, the implementation of the Handover Strategy, including the agreement on the information required for commissioning, training, asset management, future monitoring and maintenance. In terms of construction control, the evaluation of quality control and progress according with the schedule constitute essential tasks.

The compilation of all the data will set the "As-constructed" or "As-built" Information. This document constitutes, as well as the built object/facility, the main outputs at this stage completion.

2.4.4.7 Handover and Closeout

The core objective at this stage is the handover of the built object and the conclusion of the building contract.

In terms of support tasks, the evaluation of performance and the feedback of the users for corrections and for future use (on other projects) should be the main concerns. In parallel run all the activities listed on the Handover Strategy and update Project Information as required.

The update of the "As-constructed" or "As-built" Information is the most important information output to develop.

2.4.4.8 In Use

In terms of duration this is the far more important stage. There can be very complex processes and specific management requirements involved depending on the type of built object/facility, its use and scope in terms of **management requirements and metrics**. Facility management systems can be placed in action, introducing requirements from the very beginning (Handover Strategy).

In Brief, the core objectives for this stage are undertake the In Use services in accordance with the Schedule of Services and continuously update the "As-constructed" or "As-built" Information in response to new works (maintenance, operational developments, refurbishments) and ongoing owner/client/users feedback.

In terms of key support tasks and in addition to what was already mentioned, the Post-occupancy evaluation, review of Project Performance, Project Outcomes and Research and Development aspects must be concluded (PoW, 2013_2).

2.4.5 Process Integration

To create an integrated product/built object, project team must work together in an integrated way. One example that can be placed is, when designing the façade of the building, a team must take into consideration energy consumption, natural light, the structure of the building (does it requires large cross braces, etc.), fire security, and the aesthetics, to name few. Taking this example, the latest tragic events on London at Grenfell Tower constitute a major example of this need and the balance of different characteristics. Architects, mechanical engineers, interior designers, and workflow specialists must all give input for the final design; otherwise, the systems will not work together and thus will not present a high performance. With this comes the awareness and the essence of **integrated systems**.

As presented in 2.4.3 and Figure 5, there are four main stages on a construction project life-cycle: "Define user value", "Design", "Build" and "Operate". **The nexus of all of these processes is the design stage**; Figure 7. First, owners and designers must work together through many design iterations (see RIBA design stages) until both sides are able to clearly articulate and understand the values, **goals** and their inherent **ownership** of the object to be built. Then, as the design is detailed, other agents can/should be called/involved (engineers, subcontractors, among others) (depending on the type of procedure) so that the Technical design is one that still meets the established goals and can actually be built and operated.

As the design evolves, it is expected performance should be analysed periodically to ensure that the value the owner seeks and the design stay aligned. Furthermore, a high-performance building (built object) generally requires a high level of off-site fabrication, which must be planned carefully. Off-site fabrication has immense benefits to any project – it allows physical components and systems to be produced simultaneously, which is faster, in a more controlled and safer environment, and to be assembled quickly on site. Prefabrication also allows for better control of tolerances, which is not only critical for assembly but also for energy performance. However, prefabrication requires the design to be completed "on the buildable point" as definitely and early as possible (and changes cannot occur); without the knowledge and expertise of the necessary specialists during the design stages, the design will not be reliable enough to put off-site fabrication in motion.

This means that, not including **construction knowledge** in design will likely lengthen the project duration and make it more expensive because effort and time are required for redesign or for inefficient construction. Additionally, the owner/users/operators perspectives should be included in the design to ensure that the building can be operated and maintained easily. This process not only applies to new buildings; these stages also apply to the renovation or even decommissioning of a built object. Figure 7 illustrates the practice of integrating the knowledge of the main disciplines into the project delivery process.

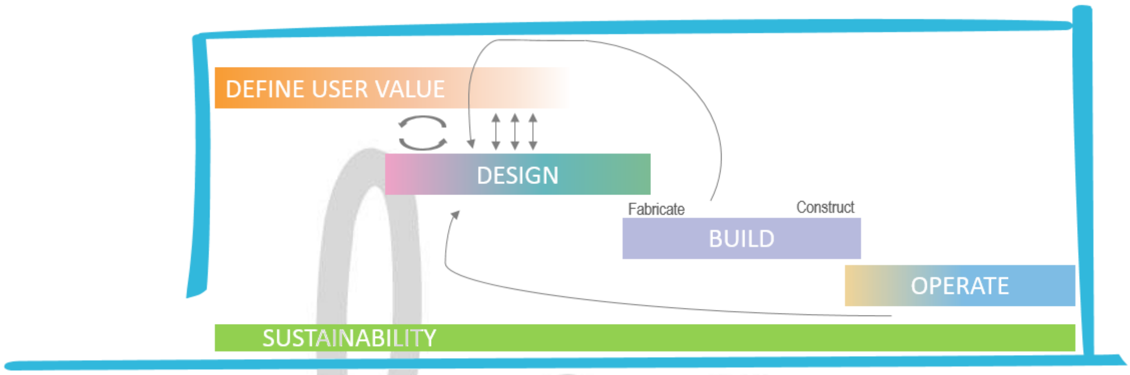


Figure 7. Integrating knowledge into the project delivery processes when it matters most. Adapted from Fischer, 2017/DPR Construction.

Project design strategies and decisions (2) must include upstream operator/user and owner values (1) and downstream construction (3), operations (4), and sustainability (5) knowledge through engagement with people having this knowledge. **Virtual modelling and simulation** can and should be used during the design stage. Three-dimensional (3D) models and related simulations help owners understand how their values might be realized and enables them to make more informed decisions over compromises or trade-offs where needed. Detailed 3D models can also be used for off-site fabrication (Fischer, 2017).

2.4.6 Overall picture of Construction Project Stages

As previously mentioned IPD is still on its infancy and it is a working definition. Its major components are part of the industry and therefore are, in many cases, well known situations.

There are several entities working on IPD. One of the most active is the AIA, where many of the contents from this part have origin. There are other references, as presented, that use other nomenclature. There are other tools and guidelines that working towards the fulfilment of one or more components of IPD and are tuned with the overall picture of integrating the construction process. For this purpose, the following image (Figure 8) frames, all the previously mentioned stages with the most updated framework for IPD stages according with AIA.

As it is possible to observe, and remembering what was mentioned on the Process integration part, "the nexus of all of these processes is the design stage". In fact, this stage in overall (has it can be divided in parts) is the core of the entire process and where all the IPD components need to take place for the success of the process.

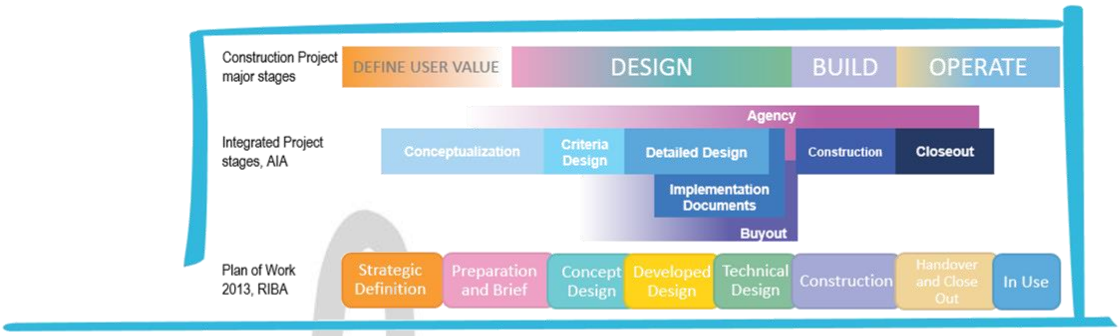


Figure 8. Common framework for the different construction project stages references

2.4.7 Specific IPD requirements

This part will endorse the essential IPD process requirements in each stage. Given the framework of Figure 8 and the objectives, key tasks and information outputs already presented for the Plan of Work stages (PoW, 2013_2), this information will be just the additional to everything previously mentioned.

Prior to the beginning of the project (prior to Conceptualization) the AIA framework sets a group of actions that are made by the owner and fit on the Strategic Definition, as Conceptualization is understood as the beginning of the design. According with AIA, the following preparatory works need to be done:

- Identify the key project participants and bring them to the project team;
- Determine the business model for the project (**owner business case**) – risk/reward structure, owner's goals, project management structure, definition of IPD contracts terms (establishment of **integrated organization** framework);
- Set up the processes for team communication/coordination, namely communication technologies and training actions (establishment of **integrated information** and **integrated process** framework);
- Set up protocols and identify the key technologies and their use during the project. Examples: data exchange protocols, model management responsibilities, change control protocols, document management system, simulation tools, modelling tools and intended outputs (establishment of **integrated information**, **integrated systems**, and **good technology** framework);

The **Conceptualization** begins with the **determination of WHAT is to be built**.

This definition is still part of the outputs of the Strategic Definition stage, namely a part of the strategic brief.

During the Conceptualization should be defined key project parameters such as, size, sustainable or green criteria or goals, performance metrics (economic, energy, maintenance, efficiency, operational, among others). Cost targets and preliminary cost structure must be developed, as well as initial schedule. These parameters, as it is possible to observe, constitute elements of the main output of the Preparation and Brief stage, the Initial Project Brief.

The **Criteria Design** is the stage corresponds to the concept design. At this stage some decisions must be fixed. The project is defined and the targets and metrics by which the success of the project will be measured are agreed upon (**high-performing building** requirements). Considering what was previously referred for this stage, the key parameters to be fixed on the Concept Design output are the following: Scope, outline design (elevations, floor plants), selection of technologies and systems (structure, envelope, water supply, HVAC, others), building components to be prefabricated, quality level of finishes, target cost and preliminary cost information, overall schedule, sustainability targets.

In terms of IPD procedure, all key trade contractors must be engaged and the procurement schedule developed.

The **Detailed Design** corresponds to the Developed and Technical Design stages. On IPD projects this stage is meant to be longer and more intense because higher achievements are required and need to be accomplished. All design decisions must be taken to assure that changes will not be necessary and the design is fully and unambiguously defined. Coordination is the main term at this point for the design. All building systems must be fully engineered and coordinated; integrated systems. Specifications are developed based on agreed and prescribed systems.

The **Implementation Documents** stage is similar on the traditional project delivery to the procurement of the contractor and the initial stage of construction on a Design bid build procedure. The focus **shifts from WHAT is being created to documenting HOW it will be implemented**. As mentioned, to fit several types of procedures, the procurement is no longer a stage, but a bar that can be adapted according with the different hypothesis. Given the intended integration of teams; integrated organization on IPD projects, this stage can be shorter due to previous contributions and high level of agreed definitions. Implementation Documents include information such as detailed schedule, procedural information (testing, commissioning, legal requirements, yard layout, among others).

The **Agency Review** is related with high-level project management that cut crosses several stages of design and construction. The main scope is provide high-level compliance information, control and assure the best possible coordination.

The **Buyout** stage is specific of IPD understood as a type of procedure. On traditional projects this process is within the construction and is part of the contractor requirements. On IPD procedures, the acquisition of products and components can be made earlier and by other stakeholders that not the contractor.

Construction is, in terms of boundaries, one of the most “peaceful” stages. It corresponds to the materialization onsite of the object/facility. Depending on the type of procedure, the design can be completed or not during construction. According to the IPD vision, the design is already closed, meaning that all the evaluations, revisions, corrections and methodology to build the object were worked out until Implementation Documents. Change orders or design queries constitute here the main difference, as on IPD contracts they should tend to zero (remember one of the IPD pillars, Figure 1). Regarding the rest, all the outputs where already mentioned on point 2.4.4.6.

The Closeout stage corresponds to the handover and close out. At this level the actions are quite similar between all types of projects. In addition to what is already mentioned it is important to highlight the warranty obligations set by the contract/legal framework, and the development of project measurements as it will be mentioned on point 2.8.

By working on the integration of stages we are partially assuring the Information Integration has it will be further mentioned in more detail.

2.5 Communication Requirements

2.5.1 Introduction

When reviewing the present framework for IPD, it is not by accident that the word communication or their synonyms appear often. In fact, the establishment of good communication channels and mutual understanding platforms are the very first base for the development of a high-performance environment for construction project development.

Communication fosters Transparency and therefore improved performance and efficiency. It is a "mandatory" aspect for effective collaboration and team project integration. The use of technology and the assumption of **"good technology"** is just valid if there is a streamlined communication flow where the transition of the information is essential. Performance requirements or early definition goals depend on the efficiency of communication between agents.

Given the above mentioned, it is easy to understand the implications of streamlined communication and information exchange for the accomplishment of IPD requirements. In terms of IPD principles, the previous paragraph addresses some of the most relevant. In what regards the IPD simple framework, the most relevant aspect in terms of communication is the contribution for **Integrated Information**. The following points will address the requirements and contributions of communication for the overall project goals accomplishment.

2.5.2 Why communication is so important?

Problems related with communication are not new on the industry (Emmerson, 1962)(Higgin and Jessop, 1965)(Latham, 1994)(DETR, 1998) and have been reported, with a focus on the intra-supplier communication within the construction sector. Demand-supply communication during the design stage; and communication between and within single demand and supply side parties, during whole the construction process. In this division the demand side contains (representatives of) owners, users, investors, among others; and the supply side architects, (sub)contractors, advisors, others (Hoezen, 2006).

As mentioned, the efficiency and effectiveness of communication fosters collaboration and streamlined information exchange/mutual understanding. This contributes to an environment that encourages mutual respect, trust and transparency. In essence, this can be found easy but assuring that this becomes a reality is one of the main drivers for the development of agreements (AIAcontracts, 2017) and the notion of IPD as a type of procedure.

Communication is the activity of conveying information. Communication has been derived from the Latin word “*communis*”, meaning to have something in common.

Communication requires a message, a sender, a channel and a receiver as shown in Figure 9 (Hollermann, 2012).

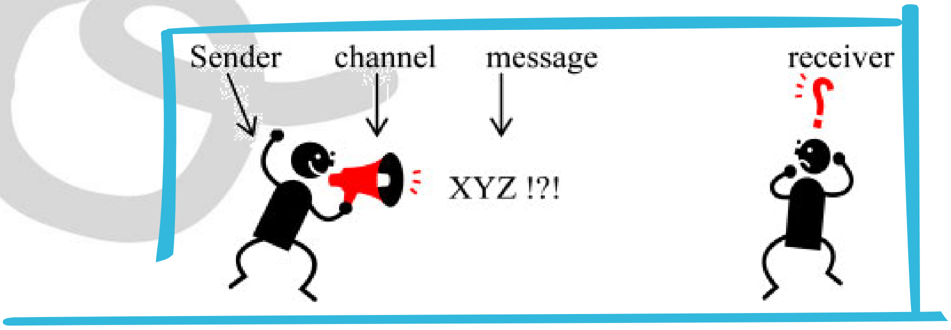


Figure 9. Communication (Hollermann, 2012)

In construction projects we have humans acting. Human communication can be distinguished into non-verbal, oral and written. In terms of information exchange and measurement of the process success rate, there are very different dimensions. Taking as an example a simple conversation between father and son, the father can **Inform** by saying “Do not do this!”. The chance of success is 10%. Increasing the information he can **Explain** saying “Do not do this, it will hurt you!”. With this type of communication he increased the chance of success to 50%. A third possibility is **Engage** and say “What do you think will happen?” At this level the chance of success increased to 90%.

This means that on construction processes the communication should follow the engagement or at least the explanation hypothesis in order to assure that the exchange is efficient. Notwithstanding, engagement implies more data/content/information/interaction.

But as mentioned, human communication has several dimensions. For oral communication different languages, different experience and education have to be considered. This comes into effect in personal conversation, by phone or in a videoconference. Attention should be given in order to assure engagement or explanation of the message between involved agents.

Written communication can be handwritten, printed or digital. The non-verbal communication, however, is often neglected, when talking about the different ways of communication in construction processes, as it will be further detailed.

2.5.3 Team Communications

The AIA IPD Guide (AIA, 2007) addresses the following in what concerns the communication requirements between team members on a construction process:

"Successful team operations rely on collaboration, which, in turn, necessarily relies on fluid and open communication. Accordingly, creating an atmosphere and mechanisms that facilitate the adequate **sharing of information** between and among team members is essential to successfully implementing IPD. The development and use of an **overarching communication protocol** streamlines communications and facilitates the **transfer of project data between participants and between technologies**. The communication protocol and other communication tools are developed **through joint workshops in which the project team discusses and decides how information will be used, managed and exchanged to ensure consistent and appropriate use** of shared information. The decisions and communication protocol established at the workshops are documented and become the project's information specification."

This text summarizes the main requirements for a streamlined construction process communication and touches several aspects that worth to be detailed.

In order to share information there must be a mean or means for exchange. This allows documents and information to be shared. There is also other relevant project related information/data that is created and used by different applications (software). In order to streamline the transfer of this data between participants and technologies, there must be classifications and interoperable languages to allow human-machine-human or human-machine-machine-human mutual understanding. At this level, we are entering on the IPD principle of **good technology**, meaning that this must be open (interoperable), manage all relevant data and establish a practical share environment between team members. This can be assumed as the **How?** part of sharing communication. But team communications is also **What?** to communicate, deciding which information is relevant in each stage of the project and for who.

Given this, one part can be resumed in what can be defined as **integrated information**. The other part is related with the **consistency of information and how it is developed during the construction stages**.

2.5.4 Integrated Information

The importance of integrated information for IPD cannot be overstated. **Integrated information is the neural system of integrated project delivery**. It is the backbone and the source of truth and insight, which allows an integrated team to make the best decisions for the project.

There are several main aspects (as it will be further detailed) of what is called **"integrated information"**, which includes consolidating fragmented information, extensive use of 3D models, a robust information technology (IT) infrastructure that allows real-time access to the latest information, and an emphasis on making decisions with all available information.

The ISO/CD 19650-1 standards presents in its introduction a picture (Figure 10) that, addressing to information management, presents stages of maturity. The higher maturity materializes the technological requirements for IPD.

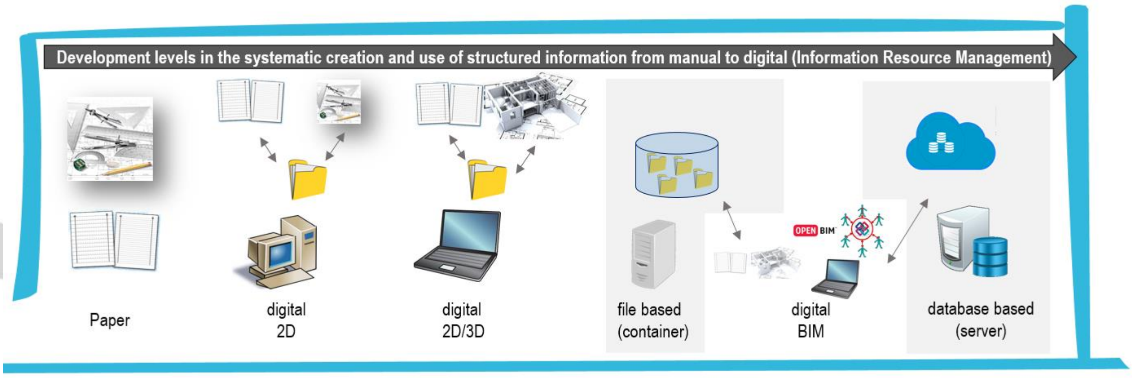


Figure 10. Stages of maturity of analogue and digital information management (adapted from ISO/CD 19650-1, 2016)

Sharing information is a linchpin of the IPD organization. Information must remain consistent across all disciplines, and everyone must have access to all current information at any time. Integrated information coordinates information (documents and data) from all disciplines to provide an accurate representation of project reality. A significant, but often overlooked, source of project delay is the time and effort spent locating, re-creating or transferring fragmented information. One study found that design teams spend 54% of their time managing information when working on fragmented teams (Flager & Haymaker, 2007).

Integrated information also provides all project participants with the necessary information to perform their responsibilities. Without it, critical information can become "siloed" within a discipline and not understandable to others. By providing a free flow between disciplines it fosters processes and **organizations integration**.

Integrated information has five characteristics (Fischer, 2017):

- It uses a **common language for sharing the information** so that it can be understood by all parties. This requires **protocols**, naming, and **interoperability standards** (classification systems, IFC technology, BuildingSmart Data Dictionary, etc.);
- It is **readily accessible by all who require the information**. Ideally, it is stored in an **organized data library** so that the information resides in one space (although that space could be virtual);

- **It is unique and reusable**. Data reflect the needs of all users and are structured to contain the information required by different parties. For example, there should be a single source of information about a wall, and it should contain information required for the architect, engineer, contractor, owner, and others (Product Data Sheets, COBie and data management through construction stages);
- **It has a source of truth**, to allow the user to determine its reliability;
- **It is aggregated from cross-functional sources** to provide a current and accurate representation of the project (good technology/interoperability).

These characteristics find already relevant tools that can and must be used. The following points will present few examples (not extensive) of tools, guidelines, technology that provide answer for these characteristics.

2.5.4.1 Common language, protocols, interoperability standards

When addressing to common language, protocols, interoperability standards we are also addressing to information that can be aggregated from different sources and crossed between them.

In terms of language, and to foster the mutual understanding there are **Classification Systems** (Kang, 2002)(Mêda, 2014)(Mêda, 2016). Most of the construction classification systems follow the ISO standard 12006-2 and are being updated for its new version from 2015 (ISO, 2015) (Mêda, 2015). The most known classification systems are the American Omniclass (Omniclass, 2013) and the UK Uniclass (RIBA, 1997). A new version of this second, the Uniclass 2, is being developed (Delamy, 2017). On the United States there are other systems such as the Uniformat or the Masterformat, with a narrower scope. These systems have been developed since the early 20 (by the AIA) and assumed the form of lists on paper format. Presently they found digital solutions as spreadsheets. Yet, they work mainly as dictionaries to help agents understand the contents. To establish correlation between systems and work as a digital tool there is the **BuildingSmart Data Dictionary**, or **BsDD** (IFD Library) (BsDD, 2017)(ISO,2007)(IFD Library, 2017). BsDD is based on ISO 12006-3 “ontology for the building and construction industry” and is used for mapping terms. In what regards the flow of information/data through software (data interoperability) the **Industry Foundation Class – IFC** is the “operating system”. It is based on ISO 16739 (IFC, 2017)(IFC, 2017_2)(ISO, 2013).

In what relates to protocols there are several guidelines that can be followed, most of them geared for the implementation of BIM during the construction process. Notwithstanding, if BIM is to be implemented towards the facility management or project life cycle, then the requirements are common with IPD. Therefore, PAS 1192 family (PAS, 2016), National BIM Standard – United States (NBSUS, 2017), the VA BIM Guide (VA, 2017), the COBIM (COBIM, 2012) or the uBIM (uBIM, 2017), just to name few, can be used.

2.5.4.2 Organized (cloud based) libraries for document exchange

In what relates to organization and storage of documents, apart from the technologic view and the use of cloud based frameworks, it is essential to know where the valid information is. Source of truth and reliability are therefore essential aspects that need to be considered above all. As previously mentioned, written communication can assume in construction different channels and formats, as presented on Table 1.

Table 1. Channels for communication in construction

Product	Flow	Miscellaneous
Drawings 2D	Gantt chart	Tables
Sketches	Precedence diagram (CPM)	Diagram
Architectural model	Time-distance diagram	Barcodes/QR code
Cave automatic virtual environment	Stereoscopic multi-user systems	Pictogram, Symbol
Virtual Tour	Flip book	Photos
Bill of Material	Animation (4D)	Reports
Influence line	User guide	Standards
Moment diagram	Method statements	Holography
Exploded view drawing	Bill of Quantities (BoQ)	Cost reports
Example	Workflow diagram	Time reports
Stencil	Flowchart	Checklists
Prototype		Bulletin Board

In general, these formats can be worked by the team each at a time, as a “stand alone” base, or simultaneously, as a .doc file being developed using “Google Drive®”. At this level, such a tool, as well as Dropbox®, Microsoft Onedrive® or others can fit the purpose. Yet, with higher requirements and other types of files, more elaborate tools need to be called.

Specifically for the exchange of models, there is the BIMServer (BIMServer, 2014), as well as other more recent products developed by the modelling software industry.

In what regards a fully solution for cloud document exchange and storage, we find the **Electronic Document Management Systems, or EDMS**’s. These systems manage production, review cycle, change control compliance and quality reporting of all project documents/records. EDMS also enable linking of related documents which would ensure schedules for example could be linked systematically to all the individual records contained in them (CR_Handover, 2016). There are several EDMS providers (EDMS, 2017).

It worth's mentioning the experience of the use of a particular EDMS on one of the major projects using integrated project philosophy and based on BIM adoption; the Crossrail project (Crossrail, 2014).

This company used only Bentley® products to avoid interoperability problems, namely with 3D models. In terms of EDMS it used on all contracts the Bentley Enterprise Bridge, or eB. For Crossrail eB Web "is used to manage all information throughout the lifecycle of change". Note that with this, it is meant to say that eB supports the information produced and delivered during the design, construction and operation. Such implementation was followed by strong investment in training actions and identification of requirements for the produced information (Bentley, 2015). The following image (Figure 11) resumes in brief the basic support and document requirements of an EDMS. In terms of Bentley systems, the implementation at Crossrail of ProjectWise and eB led to the development of a new solution, the AssetWise (AW, 2017) (PICP, 2017).

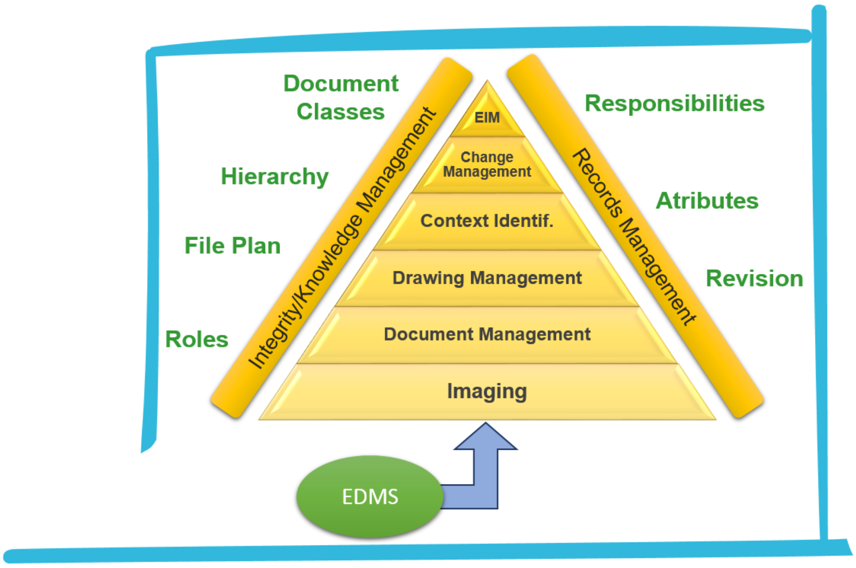


Figure 11. Basic support and document requirements of an EDMS (based on http://www.daassnet.com/new/index.php/en/products/eb.html)

2.5.4.3 Managing/exchanging data

The management and exchange of data requires common language and/or interoperability standards. At this point, IFC plays along with IFD an essential role (BS_Open, 2017). To support the data exchange there must be structures that can support it, depending on the type of data. Geometric properties and products, elements, spaces, systems, object (as to construction object), characteristics, constitute the main issues of information to exchange. There are several sources of information, multiple uses and outputs. It is a continuous effort the definition of workflows to manage and exchange data during the construction project stages and between the different agents. There are, among many, two interesting structures that worth to be briefly mentioned as they are well known and provide good background for integrated information achievement.

The **Product Data Templates – PDT and Product Data Sheets – PD**S. A PDT is a predefined way of stating the properties of a construction product. It is a template fitted for a product where manufacturers need to fill with products properties and associated values. Once completed for a specific product a PDT becomes a PDS. These structures can be developed and managed on applications; NBS Toolkit or goBIM as an example (NBS, 2015)(GoBIM, 2016), providing the templates based on the harmonized standards to meet the Construction Products Regulation - CPR (Regulation EU, 2011), ISO and National standards and BIM formats such as IFC, Revit, others, as well as COBie. Once created the PDS's the data is available (in machine readable format) for customers to find the products they want and the data they need, in the format they want it in (GoBIM, 2016).

Construction Operations Building information exchange – COBie. COBie is an international standard relating to managed asset information including space and equipment. It is closely associated with BIM approaches to design, construction and management of built assets. COBie helps capture and record important project data at the point of origin, including equipment lists, product data sheets, warranties, spare parts lists, and preventive maintenance schedules. This information is essential to support operations, maintenance and asset management once the built asset is in service. In September 2014, a code of practice regarding COBie was issued as a British Standard: "BS 1192-4:2014 Collaborative production of information Part 4: Fulfilling employer's information exchange requirements using COBie – Code of practice. (BSI, 2014)

2.5.5 Consistent information throughout project stages

A good success rate on communication processes is, as seen, very demanding, meaning that at all time the explanations must address to what is essential at that moment. IPD procedure works this flow in opposition to other types of procedures. One example is what occurs on a public contract following a Design Bid Build procedure. An interior finishing made of wall tiles must be completely specified (dimensions, shape, type of material, colour, other characteristics according with the harmonized product standard). The design team gets the information from a manufacturer, but cannot place the trademark during the bidding process. This is essential in order for the competitors (contractor companies) select the materials that best fit the requirements and allow the free competition between trademarks and products. This causes problems in terms of information flow, situation that occurs differently on IPD procedure. It is important to mention that this situation is applicable to all products, introducing problems in terms of performance goals, verification and simulations (thermal, environmental, among others), conditioning the achievement, at this level, of a high-performing built object.

A different example can be drawn for the team interaction during the project stages. At the stage of Preparation and brief it might be early to decide which type of product should be used for a piping system. If an agent from that design discipline has already an idea, it must be kept to himself and saved for a further point where the discussion of that topic will take place.

Therefore, the definition of the information matrix for the project is essential, and must take place on the beginning of the project in order for all agents/team members know the rules and focus on the priority issues. There are several guides, with more or less detail, that help on the general establishment of the requirements/contents to be worked at each stage. BS 8536-1:2015 - Briefing for design and construction – Part 1: Code of practice for facilities management (BSI, 2015) and BS 8536-2:2016 - Briefing for design and construction – Part 2: Code of practice for asset management (linear and geographical infrastructure) (BSI, 2016) or the VA BIM Object/Element Matrix Manual (Veteran Affairs, 2010) constitute good references for information definition.

2.6 Building a Team – Integrated Team

2.6.1 Introduction

Assuming that the **integration of processes** and the **integration of information** is accomplished, with data exchange and protocols for a streamlined mutual understanding, the goals for delivering an integrated project can fail widely. People/team members play an essential role on every innovative process and there are several references that point at this level the most known obstacles towards a new reality (Fischer, 2017). Resistance to change and mistrust on new procedures are within the most common situations. **Training actions** to support all team members and a **safe environment** for project development, as well as **measures** to follow up the implementation are therefore fundamental for the picture of human motivation and for the project goals. There are several approaches that can be followed as is will be further detailed. At this point, it is going to be discussed the main aspects of an integrated team. Roles and responsibilities, behaviors, boundaries, differences according to type of procedures, among others. According with the simplified framework it will be explored the **integrated organization** dimension and how it supports the achievement of **integrated systems**.

2.6.2 Project Team

The project team is the lifeblood of IPD (AIA, 2007). The key to successful Integrated Project Delivery is assembling a team (with the owner) that is committed to collaborative processes and is capable of working together effectively and with the common overriding goal of designing and constructing a successful project (AIA, 2007_2).

If trouble arises on a traditional project, the tendency is often to "batten down the hatches" and protect one's financial interests. Cooperation suffers and the project flounders. In contrast, IPD demands that participants work together when trouble arises. This "huddling" versus "hunkering" distinction is crucial. Because the hunkering down instinct in the face of trouble is so strong in the design and construction industry today, moving to an integrated, or huddling, approach is tantamount to cultural change. Therefore, the composition of the integrated team, the ability of team members to adapt to a new way of performing their services, and individual team members' behavior within the team are critical (AIA, 2007).

2.6.3 The Owner's role

It was not possible to find a correct title for this point given the importance of this agent for the process. Regardless the type of procedure, the Owner must have a clear picture/strategic vision of what he wants and how does he wants it. It is therefore a critical agent for the entire process.

On an IPD project there are main decisions to be taken on the early stages, as previously described, related with communications. In addition, it will be required a higher involvement during the construction process. The Owner takes on a substantially greater and more active role in evaluating and influencing design options. Furthermore, the Owner is required to participate in establishing project metrics at an earlier stage than is typical in a traditional project. In light of the fluid operation IPD requires, the Owner will also be called on more often to assist in resolving issues that arise on the project. As member of the decision making body, the owner will be involved on more project-related specifics and be required to act quickly in this regard to allow the project to continue efficiently (AIA, 2007).

In order to be considered a good IPD owner, the following characteristics must take place: clarity, commitment, engagement, leadership, and integrity (Fischer, 2017).

2.6.3.1 Clarity

The owner must be able to define what it wants and what the IPD team must achieve. At a minimum, this requires clearly expressing programmatic needs at a project inception/strategic definition and continuously throughout the project.

Researchers and agents involved on these processes place always emphasis on this major aspect:

> **"The owner must be very clear about their expectations for the project and what they want". (Christa Durand in Fischer, 2017)**

But clarity should also exist at a strategic level that is the owner clearly understand why he wants to do the project and set strategically the objectives. If the owner is not strategically engaged, the project will be looked at in simplistic, programmatic terms. One of the most powerful aspects of IPD is that a fully framed owner can benefit from the team help for testing its own assumptions, contributing with added value. This means that there is a joint effort in which all take benefits for a high performance project and not the team controlling the owners "vague" ideas or uncertainties. The clear definition of the strategic ideas and needs by the owner, as well as a global vision on the project development can lead to a project that effectively responds to the needs, taking advantage of the contributions and experiences of the involved team.

2.6.3.2 Commitment

A fundamental proof of owner's commitment to the process is the awareness of the needs and the willingness to support the process with training and resources.

> **"The biggest thing that people who are just starting IPD don't understand is the commitment an owner must take to this delivery method." (Robert Mitsch in Fischer, 2017)**

Experience proofs that owner's commitment is critical for behavioral change. This means that during the entire process, the owner is focused on the requirements and vision for the process, supporting and giving no opportunities to do an end run around the process. It is very difficult, at the moment, to have an entire team comfortable with IPD requirements, and not everyone believes it will be better, so the owner's ability and strength to tune the team to "do the things this way" and have a sound vision of what means "do the things this way". Further it will be detailed some of the most common problems and ways to help overcoming these difficulties; Point 2.6.6.

Ideally, commitment runs from top to bottom. But commitment needs to be continuously worked and refreshed. Several owners built support, but then as managers and executives changed, they had to re-educate the new leaders in order to maintain that support. Within large organizations, support need to be continuously refreshed.

2.6.3.3 Engagement

Passive or just a demanding attitude is not compatible with IPD. The owner must be fully engaged and an equal partner at the table (when discussing the project development, as in some aspects as previously presented, the owners role is different). Daily presence on the project and an empowered attitude towards seeking solutions, team leadership, but also be challenged by the team and provide positive feedback is essential; reciprocal relationship.

> **"What drives value into the program is owner engagement." (William Seed in Fischer, 2017)**

IPD requires much more time and effort from the owner on the project. Notwithstanding, it will also lead to improved results and higher achievement.

2.6.3.4 Leadership

Leadership is crucial for the project success. Yet, there isn't a single solution for this. Very different leadership styles can lead to outstanding results, even styles that in theory contradict everything that is assumed as trends for proper leadership. On this type of processes (IPD) and as stated, there are major components that address to collaboration, transparency, integration. This means that there is one agent that is the enabler of the entire project, sets the rules and works with the team for achievement. In brief this means that:

> **"An owner has to know when to lead and when not to lead." (Sean Graystone in Fischer, 2017)**

This can resume the essence of IPD leadership apart from the styles. IPD puts the owner on an active role, engaging with the team at a strategic level and influencing or jointly developing the solutions to project challenges. IPD leaders empower the design and construction team to take responsibility for the project, challenge owner's assumptions, and deliver the project to the agreed goals. Understand the power provided by IPD to the owner and accept the responsibility to use it effectively constitutes the major challenge.

2.6.3.5 Integrity

The owner has a key role in setting the project tone. IPD is based on optimizing the entire project and that includes the interests of the participants as well as the owner. An owner that acts only in its immediate self-interests or that doesn't act in accordance with its expressed principles will find that the participants do not fully engage in the IPD process.

> **"The owner can quickly create trust and thus creditability, by doing what we say we are going to do, every time – creating reliability." (Mark Linenberger in Fischer, 2017)**

2.6.4 Organizing the Owner and the process

IPD can be simple in concept but difficulties arise and can become rather complex when applied to specific organizations. Each one, and depending of its dimension and investment plan, might have more or less ability and resources to develop an implementation process and face more or less challenges due to the number of agents involved. Many of the above mentioned characteristics are turned to visions and behaviors, leading to the human capital of the owner (where resistances might arise). Yet, to develop an IPD process for one project or group of projects there are, as seen, other requirements.

A clear definition of the tools to be used (protocols, systems, others), a clear vision of the intended goals for the process and the organization of the human capital within the owner; in order for a clear identification and definition of who is the owner, constitute practical aspects within the owners organization process towards the implementation of IPD.

2.6.5 Building an Integrated Team

Until this point the focus was placed on the concerns of the owner and its representatives, has they can condition the development of an IPD process. Notwithstanding, there are other agents involved that play an essential role for the success or achievements on an IPD process. The AIA (AIA, 2007_2) points some aspects found essential for assembling a team towards IPD:

- Identify, at the earliest possible time, the participant roles that are most important to the project;
- Pre-qualify members (individuals and firms) of the team based on:
    - Technical competence
    - Commitment to integrated practice
    - Experience and track record
    - Proven integrity
    - Commitment to a collaborative process
- Consider interests and seek involvement of select third parties, such as building official(s), local utility companies, insurers, sureties, and other stakeholders;
- Identify the organizational and business structure best suited to Integrated Project Delivery consistent with the participants' needs and constraints. Presently, the trends point to IPD has a procedure itself, but as mentioned earlier, there are many components that foster IPD and are applicable on other types of procedures. The choice should not be bound to traditional project delivery methods, but should be flexibly adapted to the project.
- Develop project agreement(s) to define the roles and accountability/metrics of the participants. The project agreements should be synchronized to assure that parties' roles and responsibilities are defined identically in all agreements and are consistent with the agreed organizational and business models, as previously mentioned. From 2007 until nowadays a lot has been done regarding this aspect. On the next point it will be addressed a part to this subject, namely some documents with these agreement(s) recently developed. Notwithstanding, it worth's mentioning in accordance with IPD principles, the key provisions regarding compensation, obligation and risk allocation and encouragement, but also supervision and performance measurement during the process for open communication and collaboration. Issues to be considered include: Compensation and use of incentives, Communication and information exchange, Obligations and oversight, Project decision processes, Professional responsibility, Risk allocation, Insurance program.

One essential aspect of IPD is getting the team working together as early as possible. The following image summarizes the differences between agents interaction on traditional project VS integrated delivery projects, Figure 12:

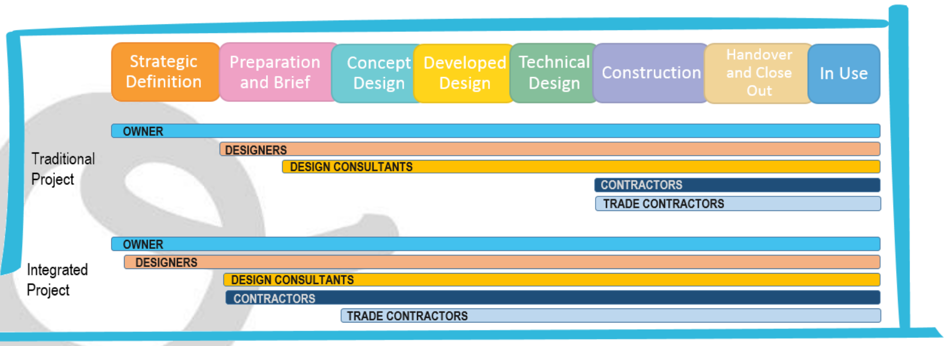


Figure 12. Agents participation on construction projects stages - Traditional VS Integrated projects.

2.6.6 Common obstacles for people on the industry

The major components that constitute IPD require a commitment from all the organization for change. This change can be more or less radical depending on the type of procedures already implemented, but it always introduces innovation at some point.

Resistance to change is inherent to human being but it can be worked with training, support and perception of the added value. Most of the resistance comes from the loss of perception of the agent role on the process and apprehension in what regards the ability to work with new processes. The notion of IPD safe environment is therefore essential in addition to the previous mentioned support. These can be assumed, at operational level, the most frequent obstacles. At management and companies level there are issues related with the involvement/commitment and share of risk that is embedded on IPD principles and that motivate the assumption of IPD as a type of procedure.

The experiences also prove that there are many stakeholders that they are fitted and tuned regarding IPD requirements. As mentioned above pre-qualification should be undertaken in order to perceive if it is really true or if they are unaware of the requirements. There are several situations where partners were dismiss due to lack of capacity after the beginning of the process. This constitutes the worst scenario in terms of implementing IPD.

Given the experiences from people that work on several IPD projects, there is in general one aspect that is essential for a specific agent become a partner of the team:

> **"I would advise a new IPD owner to pick cultural fit over everything. Pick partners that can be team players and who will work well with a group. Pick**

partners that will take responsibility for the whole project, not just their piece." (Chuck Hays in Fischer, 2017)

This situation can be simpler when talking about implementing IPD on private contracts. In what relates to Public Procurement the competition must be open and therefore the rules for bidding will have to have all the requirements that might grant higher probability of success on the choice of adequate partners.

2.6.7 Tools for team engagement

As previously mentioned, there are several actions that must be assumed by the owner in order to get an integrated team and work together making an integrated organization on an IPD project. Experiences from IPD implementation summarize the owner's experience: **"Educate, educate, educate. Educate every staff member, even VPs. Educate nonstop about the process and why we are doing IPD."** The way this education and support is performed can assume several dimensions. It can be a division from the owner that develops and trains all the agents including the members from the owner that will participate on the project or a third party (consultancy/expert) that will assume and provide all the training and support.

Crossrail's experience is among many very interesting and the recent publication of Learning Legacy Documents (Crossrail_LL, 2017) constitutes a good support for many of these topics. In respect to training and support, Crossrail established an academy, the Crossrail-Bentley Information Academy, with the objective of encouraging the delivery of best practice throughout the project supply chain. Some of the most important parts of one of the documents will be transcribed to highlight the importance of it:

"INFORMATION ACADEMY

Having project team members, contractors and the supply chain understand the Technical Information (BIM) strategy of Crossrail was identified as essential to the success of the programme. Hence an Information Academy was established aimed at enhancing internal and supply chain's knowledge, driving improvements, encouraging best practice and facilitating the transfer of knowledge to other infrastructure projects.

Leading the launch in 2012, Crossrail's Chief Executive, Andrew Wolstenholme, was a major proponent of the Academy. Recognising the need for top down support for BIM related initiatives, the Academy presented opportunities whereby Crossrail could openly share information; and enable the supply chain to innovate and produce world class information deliverables.

With Crossrail hosting an environment where open discussions between client and contractors could occur on a commercial implication-free platform, opened up the channels for effective collaboration.

The Academy provided an enabling force for all attendees to understand how Crossrail was managing information across multiple, interlinked technology platforms to create a 'Single Source of Truth' within a Common Data Environment.

The tactical goals of the Academy were to:

- Advance Crossrail's Engineering Information Management best practices
- Aid collaboration between client and employer
- Drive up standards
- Evolve solutions
- Capture and recycle lessons learned

OUTCOMES

Based upon carefully constructed benchmarking methodologies, Crossrail provides the various contracts end of (4 week) period reports to provide a RAG status snapshot of performance and compliance within a number Technical Information disciplines.

Crossrail's goal is to collaboratively convert unsatisfactory performance into world class. The typical problems which lead to poor performance is often a lack of awareness, lack of training, lack of understanding of CRL best practice principles and methodologies.

Crossrail launched the academy as an enabler for performance improvement, especially with our contractors. Therefore sessions at the Crossrail-Bentley Information Academy played a major role in creating and enriching awareness to ensure the Crossrail and delivery partner's aims to be world class could be achieved." (Cr_IA, 2017)

Other experiences might also be worked using Emotional intelligence and Big room methods (Alhava, 2016)

In parallel to the development of training, it becomes necessary to follow up and evaluate the performance of the stakeholders measuring their "commitment" with the project goals. There are several methodologies to develop evaluations as it will be presented on point 2.8. For this purpose it worth's also mentioning the evaluation matrix developed by Crossrail "Benchmarking Data Applications & Contract Performance Summaries" that explores, on a monthly base, the partners performance in terms of Modelling, Document Control, GIS and Asset Info, see Figure 13. For further detail it is possible to see this full document in: http://learninglegacy.crossrail.co.uk/documents/bim-metrics/

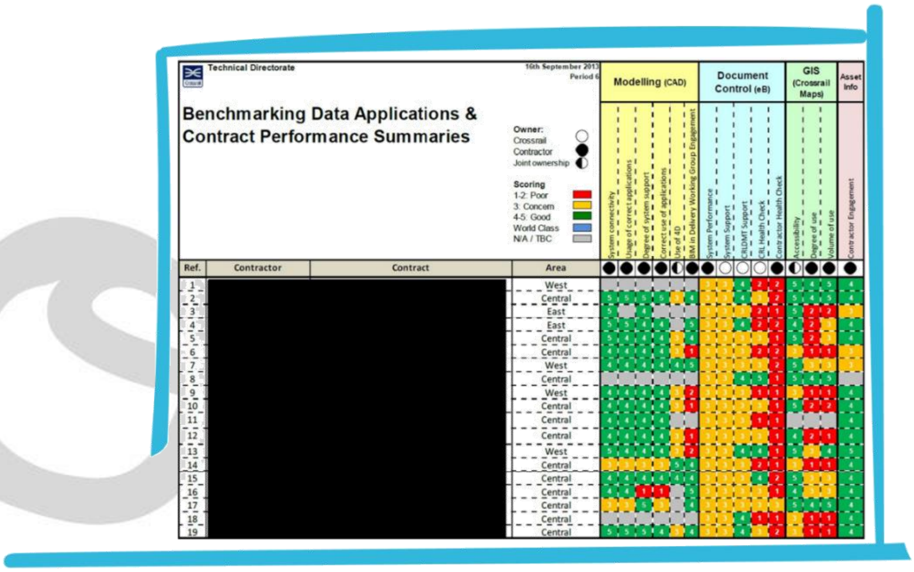


Figure 13. Initial Benchmark Data and Contract Performance Summaries (Crossrail).

2.6.8 Roles, Responsibilities

2.6.8.1 Designers

IPD relies heavily on an extensive design process that incorporates input and involvement of other team members, including contractors, during the design stage. Thus, the design process takes on added importance as other team members come to understand how the integrated project will work and how it will be completed. As a team member, the designer is necessarily involved in defining the design processes that will apply to the project.

Integrated projects allow for more extensive pre-construction efforts related to identifying and resolving potential design conflicts that traditionally may not be discovered until construction. As a result, designers are required to perform in an earlier phase certain services that are traditionally performed later in the project. The resulting advancement of services potentially increases the volume of services provided in the design stage.

Frequent interactions with other team members during the design stage necessitates that designers provide numerous iterations of their design documents to other team members for their evaluation and input. This interaction results in an additional responsibility to track throughout the design stage both the status of iterations provided to other team members and the nature and substance of the input received from them. This contributes for improved documents and **integrated systems** approach.

Also, the designer may not necessarily serve as the "gate-keeper" for the flow of communications between the owner and contractors, as it does in traditional project delivery. Ideally, communications are facilitated by the collective team structure and do not rely on a single gate-keeper, as previously mentioned.

2.6.8.2 Contractors role and responsibilities

The nature of the contractors' scope of services is primarily affected in IPD by their early involvement on the project and their participation within the integrated team. Specifically, the contractor's role increases in a significant way during early stages of design, in which contractors now provide strategic services such as schedule production, cost estimating, phasing, systems evaluation, constructability reviews, and early purchasing programs. While contractors may provide these services in traditional projects, the timing of these services is advanced.

Contractors are brought in during early project stages to provide expertise and fully participate in the design of the project. The result is a greater role in commenting on and influencing design innovation. This increased role during design requires the contractor to provide, on a continuing basis, estimating services and/or target value design services during the design stage, as well as an **integrated systems** vision that is needed to build the object.

2.6.9 Integrated Organization

From what was above mentioned, it results an **integrated organization** serving the purpose and requirements of the project as a whole. In brief, it can be summarized on the following:

Integrated organization on a construction project means that the right people from every disciplines are working together with a clear understanding of their common goals. The "right people" are those with the necessary knowledge and experience and are open to working together as an integrated team. Rather than think of themselves as members of their respective firms, **they must see themselves as members of a new organization – the project**. Everyone must come to understand that "for the good of the project" means that the project comes first, before the interests of their organization. This is a radical shift for people accustomed to fragmented and adversarial projects, and they must receive strong support from the firms for which they work.

Although integrating the individual managers of each firm in order to manage the project is difficult, creating integrated teams is harder. High-performing teams are cross-functional, multidisciplinary, and integrated on a daily, working level. They also have considerable autonomy; although they receive direction from project leadership, the team members themselves determine how to accomplish goals. Decision making must be enabled at the lowest responsible level by individuals who are closest to the sources of information and best understand the relevant issues. An IPD team is not inhibited by cumbersome "chain of command" processes or by constant second-guessing, which stymies progress and discourages the team.

Yet, everyone on the team is responsible for their own works and for the work of the team as a whole. IPD works best when team members are empowered and trusted.

But, empowered certainly does not mean disorganized. The team should develop challenging goals and protocols that detail exactly what they aim to achieve, by what methods, and what **metrics** they will use **to track progress**. By identifying and measuring these "controllable factors", the team is able to correct deficiencies and adjust their system during production, which leads to increased efficiency and effectiveness. Each person on the team must be able to describe their role and, at a deeper level, **understand how each small piece of their work contributes to the whole**, and ultimately affects achieving the shared project goals.

Leaders cannot expect team members to freely contribute their knowledge if they do not know the state of the project as it evolves. Leaders of IPD teams must find ways to allow team members to "see in": to make management, design, and construction transparent. Every member of the team must understand who the major decision-makers are, what their criteria are, and what information or analysis may be needed or useful for important decisions. The project leadership is also responsible for clearly communicating the owner's values and ensuring that all team members understand what value is and how they will deliver it.

The relative darkness enveloping most project teams is a purposeful and sensible by-product of people not wanting to expose their mistakes in an industry with a long history of finding fault and placing blame (Fulbright, 2013). As long people fear the consequences of openly sharing their thoughts or acknowledging errors as they grapple with amazingly complex problems, they will hold their cards close. That is why leadership must actively create and maintain a culture of transparent sharing (Fischer, 2017).

2.7 Delivering Integrated Project

2.7.1 Introduction

Delivering Integrated Project means, in accordance with the framework from Figure 3, delivering a high-performance building built object/facility. This is that all the requirements previously mentioned were completely achieved and during the process all the agents gave positive feedback. On the next points it will be explored the definition of high-performance built object and how it can be materialized.

2.7.2 High-performance built object

One way of think high-performance is whether the built object meets the criteria of "buildable, operable, usable and sustainable." Essentially, this means the built object can be constructed in a safe, effective way; it is easy and efficient to maintain; it is well suited for whatever it purpose is used for; and it does not harm people or the environment. The right aesthetics is part of this performance.

A truly high-performance built object supports its end users in performing their activities as optimally as possible; it is the “right” built object for what the users need. For example, a bridge should allow cars to cross it safely and quickly, even in inclement weather. A hospital should enable doctors and nurses to heal sick people and so on. This may seem like obvious performance criteria and a basic thing to demand; however, what sets a high-performance built object apart is its level of success in terms of measurable value? A high-performing hospital not only allows doctors to heal some people; it is a place that promotes the maximum possible healing in every way. Nurses don’t have to walk too much a day to do their work, maximizing therefore the visit to patients; operation rooms have enough space for necessary equipment; recovery rooms can be expanded or contracted to fit the moment needs; construction products used do not introduce contamination or do not constitute health risks; and so forth.

Values, goals, and end users are obviously unique to every project, so it is critical that the design and construction team understands the user’s goals and vision for the object to be built. **Delivering high-performance begins with an intense effort to understand and define the purpose of the object to be built**, how to measure that purpose (has it will be further detailed), and how to best achieve it. Crucially, agents from every parts of the process must be involved in the design stage, since each phase shapes the building and its performance (Fischer, 2017).

A high-performing built object is also one that efficiently uses energy, materials, and labor during both the delivery/handover and operation stages, which lowers first life cycle costs and other impacts. Most owners want to optimize life cycle operating costs (maintenance, operations, and business operations), object longevity, and first cost to construct. Yet, traditional practice focuses primarily on design construction costs only. One other aspect is also the capability of knowing what was built, with what products and when. This is applicable not only for equipment or accessories but for all construction elements placed on a built object. This allows a complete control of the object during its operation and makes possible the implementation of in use programs such as facility management, that otherwise are very difficult to set, due to unknown/incomplete information or dubious information regarding the products that were effectively placed on the object.

It may seem like a tall order to optimize the design of a built object to fit all of these criteria, but every built object will have some level of performance in these areas whether it is designed explicitly or not. In other words, **even if we design an object solely for lowest construction cost and faster delivery, the object still has a life cycle cost, but we did not plan of it intentionally, and therefore have left it entirely to chance.**

2.7.3 Achieving high-performance built object

2.7.3.1 Roadmap introduction

The value of a built object unfolds over time.

When it is completed, all agents know whether it met targets for **cost** and **schedule**. As it is commissioned, the agents, and namely the owner/users gain some idea of its ability to meet **energy and operational goals**.

But other **key goals, such as adaptability, improving users behaviour and performance, or even life cycle and maintenance cost** can be determined only after sufficient time has elapsed.

In addition, if the reasons that led to the development of the project are related with the surrounding community, it may take considerable time to get **awareness of the impacts and success of the project**.

This constitutes the basis for the metrics of the project outcomes in terms of final product, as it will be further discussed. There are other aspects to measure as the success of the process itself in terms of "integration" achievements. On the next point 2.8 all these visions and measurements will be presented. In what regards the establishment of the requirements or goals towards the achievement of a successful IPD process there are several aspects that need to be established. These are:

- Client goals – objective for the project team
- Focus on value
- Design Thinking
- Ownership of objectives

2.7.3.2 Client goals – objective for the project team

The core task of a facility development and operations team are: (1) to identify the appropriate goals and objectives that matter to the facility's clients and users to sustain their business or purpose, (2) translate them into the specific performance objectives for the use and operation of the facility and the facility development project; and then (3) through a careful design of the project organization and its work processes and corresponding objectives and metrics, (4) design and build the best possible facility/built object that enables sustainable use and operation (Figure 14). This sounds straightforward enough but is, of course, difficult to execute across the many organizational, temporal, and physical boundaries and scales and for the many economic, environmental, and social performance goals that shape each unique facility/built object. Figure 14 shows the two main types of goals and the main types of performance objectives necessary to define the value of a facility. The combination of these goals and objectives defines **project value**. The industry experience is that professionals are mostly anxious to get going on the design and construction of the facility because, after all, that's what they are paid to do. But without the right "design" of the project organization, including how the work is going to be done, the experience and the result of the design and construction efforts are unlikely to be satisfying. Also note that without clearly defined performance objectives for the built object and without understanding what the users and client value, there is no clear yardstick to distinguish a good design solution from a poor one in terms of what really matter to the client.

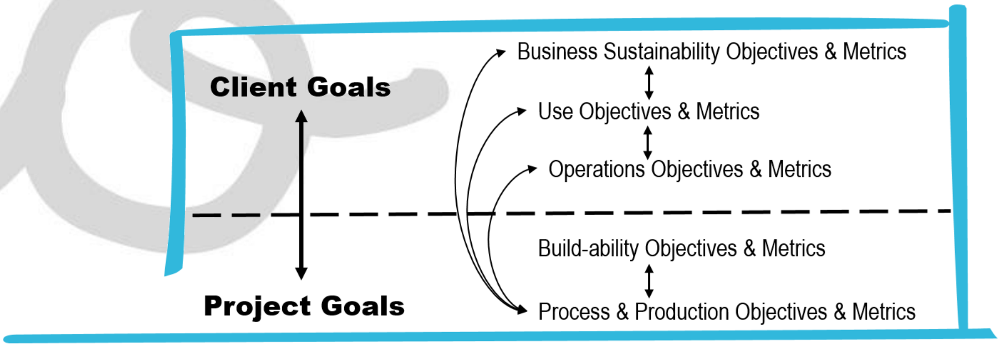


Figure 14. Client and project goals and objectives (Fischer, 2017).

Translating the business goals of the client into building-focused client goals and then into specific project goals related to the users, operators, and **integrated team** is very challenging. Establishing measurable objectives that capture the goals and guide the development of the project is equally difficult. Hence, the formal requirements often inadequately describe the value desired by the users and owner.

2.7.3.3 Focus on value

A High performance facility/built object enables its users to create the value they must deliver to thrive in their own business. As an example, a bridge allows a number of cars to cross each day helping a transportation company meeting its goal of enabling people to go places. The work of designers, contractors, and operators accomplishes this performance and enables this value through the efficient allocation of products and technical, financial, and human resources. This is a complex endeavor due to the difficulty in predicting many aspects that must be considered when making decisions about a facility. These decisions affect the duration and cost of the design and construction stages or the carbon dioxide (CO_2) footprint during operations, or the expected durability of the built object. It is expected the optimization of performance across all the cost and income (Figure 15). Yet this is very challenging to accomplish given the unique nature of each built object on its economic, environmental and social context. Today's project delivery process often attempts to optimize the design and construction cost and duration (goals 1 and 2 in Figure 15).

Notwithstanding, it is difficult to contrast value on the following example and in a generic situation:

An additional month of design time against the value of opening the facility/built object one month earlier. With an additional month of design time, could the design team have come up with a way to shorten the construction duration by more than one month or increase the income of the facility by more than a month's worth of revenue, and so forth?

The value of a built object, and the cost to achieve it, are reflected in the different costs and revenue from Figure 15.

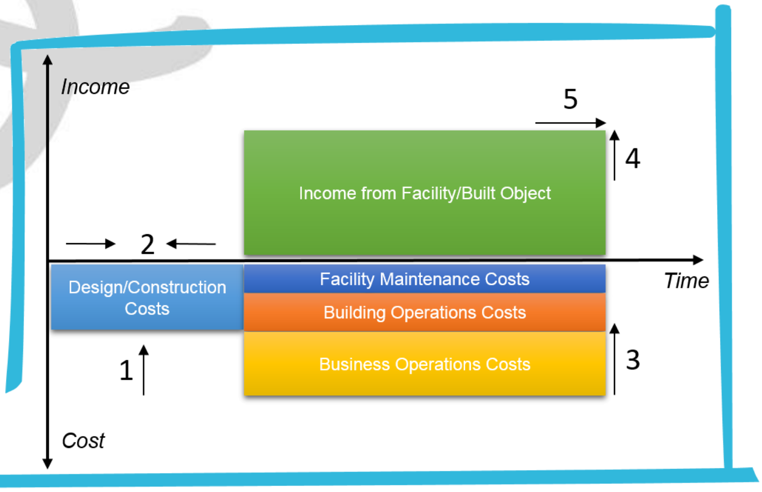


Figure 15. Client and project goals and objectives (Fischer, 2017).

Optimizing the values and costs requires the right blend of the four performance types, previously mentioned; **buildable, operable, usable and sustainable**.

It is absolutely essential that the project delivery team considers all facility performance goals and objectives during the design and construction stages. By connecting the different costs and income with the main stages of a facility's "creation" and use, a framework is needed to connect the levers where a project team has to influence performance with the performance that is sought, i.e. independent variables with dependent variables.

"Creating a uniquely valuable high-performing built object requires Design Thinking." (Herbert Simon in Fischer, 2017)

2.7.3.4 Design Thinking

More than four decades ago, both Simon and Jonh Gero developed theories to demystify design. Gero explained design as a process of creating structure or form to produce behaviors that allow people to function in ways they want (Gero, Tham & Lee, 1992). In simple terms: first, one must understand the function of the thing being designed that is establish how it needs to perform. Then one has to consider how the thing has to work to meet the needs. Then one should draw on and adapt past experience to conceive the structure of the thing. The so-called "magic of design" involves such cycles of analysis, synthesis, and evaluation to establish the function, structure or form, and behaviour of what is being designed.

Specifically, for construction projects, in 1896 the American architect Louis Sullivan coined the phrase "form follows function" (Sullivan, 1896). But facilities/built objects rarely have only one function or performance requirement. Moreover, there are typically many possible solutions of forms that address the function or performance requirements in differing ways. "In the real world", the solution chosen by the project team should optimize the blend of performance types consistent with the project's values. To do so, the team needs a logical and consistent framework that intersects what the team can control (the "levers" or independent variables) and the resultant outcomes (dependent variables).

Making something buildable, operable, usable, and sustainable are imperative concerns in delivering functionality. Thinking about these four concerns and their application for facilities/built objects, any decision about a physical component included in it brings with it a particular mix of organizations and processes.

To bring a design thinking approach to construction, applied research carried out at Center for Integrated Facility Engineering – CIFE showed that a project organization or delivery team adds value to a building by applying design thinking to three domains: the **product**, work **process**, and the **organization**. This is, in fact, aligned with the framework of IPD has well as the major components, principles. In essence, these are the three levers for affecting project outcomes: A team can change the characteristics of the product (the object/facility being built), it can change what people are doing (the work process), or it can change how people are organizing themselves. The CIFE Product-Organization-Process matrix - POP framework can be represented in a 3 x 3 matrix with the three design questions (function, form or structure, and behavior); Table 2.

Table 2. CIFE POP Model

	Product	Organization	Process
Function	What is the purpose/use?		
Structure/Form	What is the structure/form?		
Structure/Form	What does this look like? How is it put together?		
Behavior	How will it/we perform?		

The team can decide on the shape, layout, and makeup of the facility itself. These decisions can be called broadly product decisions once they address to the physical components-products-of a facility. The team can also decide who to involve, when and how. These are organization decisions. Finally, it has to decide what the different project participants will do, when and in what sequence. These are process decisions.

The value of POP framework is that is a mutually exclusive, collectively exhaustive representation of a facility and its stakeholders over time. In not only treats the design of a facility as a product design problem, but sees the design of a facility holistically as the design of a facility's products, organizations, and processes (POP, 2017).

The POP framework can be applied at the **enterprise/client**, **user/usability** and **facility operations** levels; Figure 16. The POP framework is also consistent with the "triple bottom line", the simultaneous achievement of economic, social, and sustainability goals/objectives. (Fischer, 2017)

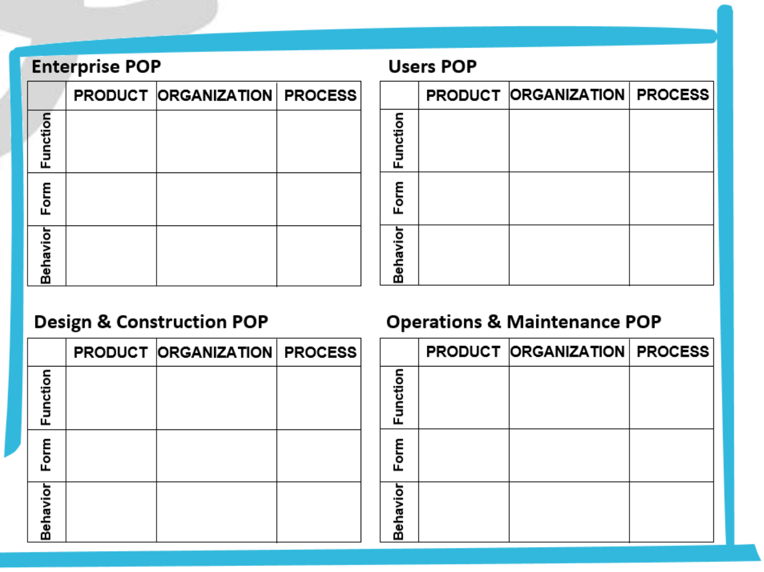


Figure 16. POP models together (based on Fischer, 2017).

Leaders of every **integrated project team** can use the POP model to design what they will deliver and how. Answering the questions from Table 3 allows leaders to understand the product they need to create and why. When they do, leaders will see the kind of **integrated organization** and **processes** the need to create.

Design thinking provides tools for the organization and systematization/prioritization of goals/objectives. One additional aspect that needs to be settled regarding these goals is their **ownership**, agent's main interest or responsibility for compliance.

Table 3. Project Delivery Team POP Model (Fischer, 2017)

	Product	Organization	Process
Function	What value-creating activities will the high-performance facility support?	What are your objectives? How will we achieve them? What must we control? What do we expect to accomplish?	What will we produce (scope/quality)?
Structure/ Form	What spaces and components and systems will make up the built object? How will they be arranged?	Who will make decisions about value? How will we organize ourselves?	What methods will the teams use? What steps will we take? How will we communicate?
Behavior	What predictions will we make? What metric will we use?	What are the measurable outcomes for the team as a whole?	What are our production and outcome metrics?

2.7.3.5 Ownership of objectives

The only way for objectives to be established and validated so they can be used to guide design and construction decisions is to identify an "owner" for each of them. Each owner must be very knowledgeable about the objective and must have a significant stake in ensuring that the facility meets the particular performance target. Otherwise, they cannot be respected advocates for an objective and cannot be involved in setting, prioritizing, and proactively managing a project with these four types of objectives.

The client's business organization should be primarily responsible for the sustainability objectives, as the new built object should contribute to the **prosperity of the client's business in its economic, environmental and social context**. The users of the building need to articulate usability objectives. The operators (e.g., facility maintenance staff), should own the operability objectives, and the design and construction team has to bring the buildability perspective to the table.

> **The right Advocate – Although an owner may have critical goals for operational efficiency and sustainability, we have seen instances where the owner's project manager – who is likely being reviewed based on meeting a budget or schedule – will not defend the owner's legitimate other goals against a cost or schedule threat. In these instances, the project manager is not the right advocate for the owner's usable, operational, or sustainability objectives.**

It is critical that these objectives are considered as early as possible to avoid suboptimization of the building for a subset of these objectives. It is also critical that these objectives are considered in all major decisions, which requires continuity of staffing and definition of the methods for predicting and measuring each objective. Anything short of that, will likely dilute the objectives that do not have a formal owner as other stakeholders and team members advocate for design solutions that best meet their needs.

A final key point is that the performance of design solutions under consideration needs to be predicted and eventually measured so that the team can guide project toward the highest possible value and can demonstrate this value through measurements (Fischer, 2017).

2.7.4 Brief comparison between IPD other delivery models/procedures

IPD allow for a dynamic, transparent and holistic process that benefits all project participants. The following tables represent qualitative assessments of how IPD can be differentiated from other delivery models/procedures. The delivery models show traditional methods, but do not take into account various contract models such as Guaranteed Maximum Price (GMP). The chosen models are comparators to IPD; Design Bid Build, Multi-Prime, Construction Manager at Risk (CM at Risk) and Design Build. These represent the predominant delivery models used in the industry. Other situations as Public Private Partnerships were not included as they embrace one of the four models to deliver the design and construction of the built object within the umbrella of the longer contract for the facility operation. The charts were developed from the broad experience of the IPD Steering Committee members and contributors and do not represent any research or collected field data from any specific projects. The overarching message is that the only delivery model where all the project stakeholders can benefit in all the studies is IPD, and sometimes Design Build.

Table 4: Who benefits if the costs comes in lower or the schedule shorter depending on delivery model type?

	Owner	Designer	Builder	Trade
Design Bid Build	No	No	Yes	Yes
Multi-Prime (hard bid)	No	No	Yes	Yes
CM at Risk	No	No	Yes	Yes
Design Build	No	Yes	Yes	Yes
IPD	Yes	Yes	Yes	Yes

In Table 4; one might not understand why the owner does not benefit with the costs coming in lower than initially contracted. Traditional contracts do not require the sharing of savings on a project with the owner. Project stakeholders are incentivized to reduce costs for their own benefit, yet the owner does not always receive this benefit if the contract is not transparent and does not share these outcomes.

Table 5: Who is incentivized to keep the cost down or reduce the schedule for the owner when changes occur?

	Owner	Designer	Builder	Trade
Design Bid Build	Yes	No	No	Yes
Multi-Prime (hard bid)	Yes	No	No	Yes
CM at Risk	Yes	No	No	Yes
Design Build	Yes	No	No	Yes
IPD	Yes	Yes	Yes	Yes

Table 5 shows that under traditional methods the owner is incentivized to keep costs reduced as project requirements change, but the other project stakeholders are not. This characterization of change is true for both owner generated changes, unforeseen conditions and errors/omissions. Under IPD, though, the team is incentivized to keep costs down on a project when changes occur because the team is all being supplied from the same source that will reward them. The transparent and single pool of monies in an IPD model enables ownership from all project stakeholders for project success.

Table 6: Who is incentivized to improve construction processes?

	Owner	Designer	Builder	Trade
Design Bid Build	Yes	No	No	No
Multi-Prime (hard bid)	Yes	No	No	No
CM at Risk	Yes	No	Yes	Yes
Design Build	Yes	Yes	Yes	Yes
IPD	Yes	Yes	Yes	Yes

Table 6 begins to identify who wants to improve the quality and methodology of how the project is delivered. The construction industry is in a transition to embrace more advanced methods of making built objects, as other manufacturing fields have. IPD, and sometimes Design-Build, offer all the project team stakeholders the benefit when advanced delivery methodologies are coordinated with others and the impact might not be cost neutral.

Table 7: Who is incentivized to improve building performance for the lifecycle?

	Owner	Designer	Builder	Trade
Design Bid Build	Yes	No	No	No
Multi-Prime (hard bid)	Yes	No	No	No
CM at Risk	Yes	No	No	No
Design Build	Yes	No	No	No
IPD	Yes	Yes	Yes	Yes

Table 7 aligns project delivery with building performance. The main message is that only through dynamic, transparent and holistic process benefiting all project participants. The industry will be incentivized to move the needle on how built objects perform. Building system technologies and the actual functional requirements are constantly changing. Traditional contracts are set up where the requirements and functionality are fixed. In addition, design fees are also considered to be part of first cost competitive analysis by owners and do not allow for lifecycle design. Since the lifecycle of a building is a significant portion of the building's cost for the initial capital outlay, the industry needs to provide a methodology where the project delivery can support the eventual operations of the building.

2.8 Measurement of Integrated Project Outcomes

2.8.1 Introduction

In IPD, as in traditional projects, the risk of failing to meet expectations remains. Because success in IPD is measured by expressly stated shared goals, and in many cases financial consequences flow from attaining, or failing to attain, such goals, IPD agreements clearly spell out project goals and the consequences of success or failure (AIAcontracts, 2017).

The IPD project plan includes project metric values and reporting intervals to monitor progress of the project. These metrics include overall performance of the project as well as the traditional cost, schedule, and scope measurements. The POP matrixes, previously mentioned, offer an additional tools to organize and align the many performances (objectives, metrics and targets) by organizing the global project on the following categories: **Product** (what it is, what is made of), **Organization** (who is involved, who moves the project forward), and **Process** (what is everyone doing) perspectives (Fischer, 2017):

- **Product performance** metrics relate the **usability, buildability, operability, and sustainability** objectives to the product. They describe how the facility should function or perform and how it is performing or behaving. These metrics are the means for predicting outcomes and making decisions during design. Measured over the first year of operation, these metrics become product outcome metrics;
- **Project organization** metrics give insight into how well the project organization is able to manage toward the **cost, schedule, quality, and safety objectives**;
- **Process metrics** measure the **results of the processes team members are using** to achieve project goals. These are typically leading indicators of project organization/team performance. Based on the process metrics, team leaders and members can learn and improve their practices, methods, and tools, and thus project outcomes. Production metrics fall into this category. They are metrics for work processes that contribute directly to building the physical product itself; what is going to be delivered to the client.

The following points will address to each one of these categories and provide examples of tools that can help on the establishment/support of metrics for measuring IPD projects.

2.8.2 Product Performance

2.8.2.1 Goals & Standards

Although the team may present alternatives and counsel the owner, some goals are “owned by the owner”. The owner determines its program and what it wants to achieve. However, standards based upon goals and used to judge project success and compensation are jointly agreed upon. It’s necessary for all parties to be comfortable with the agreed-upon anticipated outcomes, as they may affect potential bonus and compensation structures.

If the goals are simply economic, standards of project duration and cost may adequately measure attainment of these goals. Objective performance criteria, such as energy efficiency, are also easily determined. Quality of construction and design creativity are less easily measured. These factors may require a weighted index, comparison structures, and independent evaluators.

The team also agrees on when the standards will be measured. For example, the team determines if energy efficiency is measured during commissioning, or is averaged over a season or seasons. If lowered maintenance cost is a goal, the team determines when success is measured.

2.8.2.2 Operational Performance

The establishment of performance criteria for major building systems within a project is made during early design and refined as the design proceeds. These are aligned with the project goals and set with the advice of the major trades participating in the project along with the associated design professionals.

The opportunity exists for financial performance metrics of the completed project to be established and tracked after completion. The contribution that the project team makes to the ongoing success of the performance of the finished project due to quality of design and implementation could lead to royalty or other long term financial profit sharing arrangements for those key participants.

2.8.2.3 Sustainability

One key area of opportunity for improvement from traditional delivery approaches is to set more aggressive goals for sustainability. Metrics can be established for lifecycle goals for all aspects of a project. Ratings criteria such as Green Globes, LEED® or SB Tool may be melded into the overall goals and incremental steps monitored throughout the design and delivery process. The opportunity also exists to set goals for carbon footprint and incorporation of alternative energies.

The chapter 11 of Integrating Project Delivery (Fischer, 2017) as well as table 5.8 identify some guidelines and parameters towards these metrics.

2.8.3 Project organization

2.8.3.1 Project Cost

The overall project cost is a prime metric that is established at the project inception and tracked throughout the life of the project with agreed upon emphasis on life cycle and sustainability components. Included are the cost of the actual work, non-incentive based compensation (fees for services) and appropriate contingencies. The potential for a direct connection between the design and quantity survey during all phases creates a powerful tool to determine and manage the project cost. This is one of the prime opportunities to see the efficiency possible with IPD.

A significant benefit of IPD is the opportunity to replace value engineering with target pricing or target value design processes (a form of estimated budgeting). Under many IPD arrangements, significant consequences flow from exceeding (or beating) the target price. Early in conceptualization, the team confirms whether a project can be built for the funds available that will satisfy the owner’s goals. Assuming the team validates the budget assumptions, it then pursues target value design. Unlike traditional design processes where design, budgeting, and then redesign is an iterative process, a target value design process uses immediate feedback on budget, schedule and quality to inform the development of the design. It promotes designing to a detailed estimate, rather than estimating a detailed design. For this to be accomplished, information needs to be communicated effectively to all interested parties, feedback received, and decisions made on an open and rational basis. If this is properly done, conventional “value engineering” vanishes. Moreover, by tying the decision process to the schedule, alternatives that require information can proceed on parallel paths until the appropriate “last responsible moment.”

To the extent that setting the target price is a collaborative exercise, there are a number of issues to consider. In the first instance, each project participant has a direct pecuniary interest in where the target price is set. The owner’s interests often favor a lower price, whereas the designers or contractors may have a financial incentive to seek a higher target price. This conflict is managed through careful participant selection, open book estimating, and proper use of independent consultants.

2.8.3.2 Project Schedule

One of the main potential benefits of IPD is the reduction of construction time due to the extensive planning and changes to project processes. This benefit is a common determinant in selecting IPD as a preferred process by owners. The ability to link schedule, phasing and detailed construction sequencing during design will provide efficiencies in material procurement. Early ordering of materials by key supporting participant trade contractors to coordinate with the development of the design reduces the time from the completion of design to the beginning of active work on the site of a project.

2.8.3.3 Project Quality

New technological tools available to IPD team members, including BIM, provide the opportunity to reduce errors within design documents as well as conflicts between trades--all well before purchasing of systems and products. Collaboration among the participants leverages these tools to create an atmosphere where quality of service, design and execution are integral to the project.

The measurement of quality is based upon metrics appropriate to the project type and is compared to previously completed projects of similar nature. As more IPD projects are undertaken by an owner or an industry, quality standards may increase.

2.8.4 Process metrics

Although it comes in last, the process metrics is the basis for the fulfilment of IPD as it measures the performance of IPD principles or the level of accomplishment of IPD goals, according with its major components/simplified framework. In what regards this metric, there are several references that can be used. One that was already mentioned is specifically targeted for the accomplishment in terms of information integration as it was assumed to be a major goal from the owner to be fulfilled. Therefore, the Crossrail metrics for Project Information Compliance Principles (PICP, 2017).

One other interesting reference is the Australasian Project Team Integration Workbook (ACIF, 2014). This publication has the main purpose of:

“inform project sponsors and project team members of the steps they need to take to achieve the highest possible level of integration of contractors and suppliers with designers and other consultants in project teams to deliver optimal project outcomes. The function of integration is the objective, rather than the form of an **Integrated Project Team**. This Workbook identifies 18 separate decisions, listed below, that need to be made and that will influence the way in which project teams are created and managed. Each is capable of several possible outcomes ranging from “Red” or business-as-usual to “Blue” leading practice.” Table 8 identifies the 18 aspects that are evaluated. Figure 17 presents one example of the framework for a specific aspect/decision; decision #13 Collaboration and communication.

Table 8. Aspects/decisions evaluated (ACIF, 2014)

Project sponsor/owner decisions	Project delivery team decisions
1. Environment & culture	7. Client business integration
2. Trusting relationships	8. Scope management
3. Project Leadership	9. Team selection
4. Client risk tolerance	10. Team integration
5. Financial management	11. Project start up
6. Project delivery strategy	12. Stakeholder involvement
	13. Collaboration & communication
	14. Wasted effort
	15. On-the-job learning
	16. Project control standards
	17. Technical, OHS, environmental
	18. Continuous improvement

13. Collaboration and communication

Why is this important?

Traditional project roles and responsibilities ensure that project team members 'live in silos' and communicate formally through organisation structures. This limits collaboration and value adding, resulting in significant wasted effort, confrontation and angst. A "Green" project works toward being a virtual organisation with open communication and trans-disciplinary problem prevention. BIM intelligently used also can drive a "Green" outcome.

Decision #13	Decision Value				
Collaboration & Communication	Very limited co-operation and collaboration between team members. 'Us and them' attitude exists.	Selfish focus to make a profit. Hierarchal communications via project manager.	Client service focus exists but restrained by contracts. Responsibilities taken seriously and there's concern for others .	Client service focus to achieve business case. Project partnering exists with project treated more important than employers.	Service focus to delight end-users. Project co-operative exists with end-user treated as more important than project.
Hear	*"It's hopeless having to work with these fools."*	*"I'm alright, it's not my fault. Silos protect me. Email copy everyone"*	*"I wonder what the others think. Delays cost us. I'd like to help, but..."*	*"I don't want to let anyone down. Talk to each other but keep me informed."*	*"We have an Integrated project team with open communication and information."*
See	Solicitors approving correspondence for claim building. Large un-actioned files.	Supervised employees with 'turf protection'. Documentation delays. Un-actioned files.	Silos and 'turf protection' are outlawed but linger on. Barriers to communication recognised.	Integrated teamwork of design and construction. IT protocols agreed. 3D CAD used by all.	Integrated self-managed trans-disciplinary project team of all suppliers.
Likely outcome					
Target outcome					
Issues					
Actions					
Metrics					

Figure 17. Example of the framework for a specific aspect/decision; decision #13 Collaboration and communication (ACIF, 2014)

2.8.5 Conclusion

As mentioned these are just some guidelines/tools/examples that can be followed. Specific agreements might define own metrics of each one of the categories or set a different organization for the measurement of the outcomes.

One aspect that is essential to be aware is the need to develop measurements during the process in order to get a global perception over the achievements and behavior of the all and its parts.

2.9 Final note

As it was stated, IPD is still in its infancy (AIA, 2014) and therefore is still a work in process where continuous updated will be made.

The scope of these notes were to contribute for the awareness of IPD as a delivery model, its major components and requirements.

The presented simplified framework "frames" all the principles and set the way for exploring significant aspects that compose IPD. The combination of that framework with the topics explored on the different points lead to the following resume schema, Figure18.

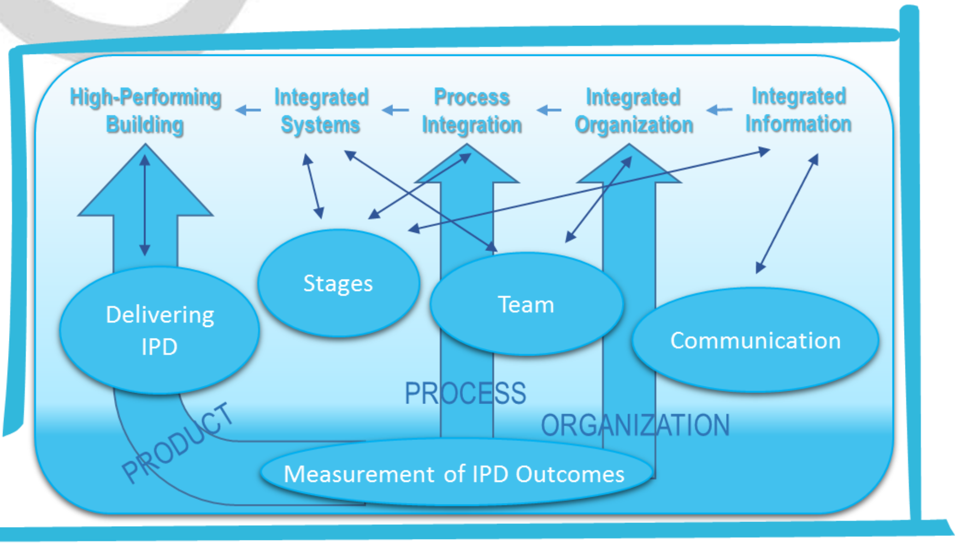


Figure 18. Relation between points, simplified framework and measurement metrics.

Main highlights:

The trends point to IPD as a type of procedure;

There are several agreements that support this vision and others that fit other types of procedures;

The owner and its commitment with the process is a determinant aspect for the success of the endeavor;

The road towards IPD is made of several components that isolated and combined contribute for the sustainability of the industry and therefore, all agents must be aware of the different aspects and how they influence their work and contribute for a better sector in terms of process, organization and products.

2.10 References

Construction 2030, 2015 – Construction 2030 – A global forecast for the construction industry to 2030. Oxford Economics, ISBN 978-0-9564207-9-4, London, UK.

WEF, 2016 – Industry Agenda – Shaping the Future of Construction – A Breakthrough in Mindset and Technology. World Economic Forum, Geneva, Switzerland.

EC Strategy, 2012 – European Commission. Strategy for the sustainable competitiveness of the construction sector and its Enterprises, COM (2012) 433 final. European Commission, Brussels, 2012.

McKinsey, 2016 – Imaging construction's digital future. http://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/imagining-constructions-digital-future. June 2017.

KPMG/PMI, 2013 – Study on project schedule and cost overruns – Expedite infrastructure projects. KPMG/PMI, India.

Pramen, 2013 – Magnitude of Construction Cost and Schedule Overruns in Public Work Projects. Journal of Construction Engineering Volume 2013 (2013), Article ID 935978, 9 pages http://dx.doi.org/10.1155/2013/935978.

Wolstenholme, 2009 – Never waste a Good Crisis - A Review of Progress since Rethinking Construction and Thoughts for Our Future, Constructing Excellence, London.

Lou, 2017 – Project extranets and developments in project collaboration. Advances in construction ICT and e-Business – CIB, Routledge, ISBN 978-1-315-69069-8 New York, USA.

Eilif, 2017 – BIM understanding and activities. 2nd International Conference on Building Information Modelling (BIM) in Design, Construction and Operations, 10 - 12 May, 2017 Alicante, Spain.

AIA, 2014 – Integrated Project Delivery: An updated Working Definition, Version 3 updated 7/15/14. AIA|CC - The American Institute of Architects, California Council, Sacramento, USA.

AIA, 2007 – Integrated Project Delivery: A Guide, Version 1. AIA| National and AIA|CC - The American Institute of Architects, California Council, Sacramento, USA.

CIB_Pub.370, 2013 – Owen, R., Amor, R., Dickinson, J., Prins, M., Kiviniemi, A. Research Roadmap Report Integrated Design & Delivery Solutions (IDDS). CIB International Council for Research and Innovation in Building and Construction – Publication 370, Rotterdam, March 2013.

AIA, 2007_2 – Integrated Project Delivery: A Working Definition, Version 2 updated 06/13/2007. AIA|CC - The American Institute of Architects, California Council, Sacramento, USA.

Fischer, 2017 – Fischer, M., Ashcraft, H., Reed, D., Khanzode, A. - Integrating Project Delivery. Wiley, ISBN 978-0-470-58735-5, New Jersey, USA.

ISO 21500, 2012 – Guidance on Project Management. International Organization for Standardization, Geneva, Switzerland.

Sousa, 2008 - Sousa, H., Moreira, J. Mêda, P. – ProNIC© and the evolution of the Construction Information Classification Systems, in: GEQUALTEC (Ed.), GESCON 2008 – International Forum on Construction Management, FEUP, Porto, pp. 35-47.

PoW, 2013 - RIBA Plan of Work 2013. http://www.architecture.com/files/ribaprofessionalservices/practice/frontlineletters/ribaplanofwork2013consultationdocument.pdf. October 2013.

PoW, 2013_2 - Sinclair, D. - Guide to using the RIBA Plan of Work 2013. ISBN 9781859465042. RIBA Publications Limited, London, UK.

CIB_TG90, 2017 - http://www.cibworld.nl/app/export/CQpxayvX/20158981/38d9f82b35231306ac6140b89ce560d4/TG90%20Research%20Roadmap%20Call%20for%20Case%20Studies.pdf. June 2017.

Emmerson, 1962 - Emmerson, H. 1962, Survey of Problems Before the Construction Industries: A Report prepared for the Minister of Works, HMSO.

Higgin and Jessop, 1965 - Higgin, G. and Jessop, N. 1965, Communication in the Building Industry: The Report of a Pilot Study, Tavistock.

Latham, 1994 - Latham, M. 1994, Constructing the Team, HMSO.

DETR, 1998 - DETR 1998, The Report of the Construction Industry Task Force: Rethinking Construction (The Egan Report), HMSO.

Hoezen, 2006 – Hoezen, M., Reymen, I., & Dewulf, G. P. M. R. (2006). The problem of communication in construction. Proceedings of the joint CIB, Tensinet, IASS International Conference on Adaptability in Design and Construction, Eindhoven, the Netherlands.

AIAcontracts, 2017 – AIA Contract Documents – IPD Family. https://www.aiacontracts.org/contract-doc-pages/27166-integrated-project-delivery-ipd-family. June 2017.

Hollermann, 2012 - Hollermann, S.; et al., BIM – a challenge for communication between parties involved in construction, ECPPM 2012 - 9th European Conference on Product and Process Modelling, Reykjavik - Iceland, 25-27th July, 833-838.

ISO/CD 19650-1, 2016 - Information management using building information modelling - Part 1: Concepts and Principles. International Organization for Standardization, Geneva, Switzerland.

Flager & Haymaker, 2007 - Flager F. and J. Haymaker (2007). A Comparison of Multidisciplinary Design, Analysis and Optimization Processes in the Building Construction and Aerospace Industries. 24th International Conference on Information Technology in Construction. I. Smith. Maribor, Slovenia: 625-630.

Kang, 2002 - Kang, L.S., Paulson, B.C.. Adaptability of information classification system for civil works. Journal of Construction Engineering and Management, (12), (2002), 10-12.

Mêda, 2014 - Mêda, P., 2014a. Integrated Construction Organization - Contributions to the Portuguese Framework. Master Thesis in Civil Engineering, Faculty of Engineering of the University of Porto, Portugal.

Mêda, 2016 - MÊDA, P.; HJELSETH, E.; SOUSA, H. – Construction information framework-the role of classification systems, ECPPM2016 - 11th European Conference on Product and Process Modelling, Limassol, Cyprus, 7-9 September.

ISO, 2015 – ISO 12006-2:2015 Building construction -- Organization of information about construction works - Part 2: Framework for classification, International Organization for Standardization, Oslo.

Mêda, 2015 - MÊDA, P.; SOUSA, H. – "ISO 12006-2:2015 Framework for construction classification". 8th AECEF - Symposium on New Actions and Roles of Civil Engineers - Sustainability and Energy, 5-6 November, Porto FEUP, Portugal;

Omniclass, 2013 - Omniclass site (http://www.omniclass.org/). July 2013.

RIBA, 1997 - RIBA. Uniclass - Unified Classification for the Construction Industry, 1st edition, RIBA publications, UK, 1997.

Delamy, 2017 - https://toolkit.thenbs.com/articles/classification/. July 2017.

BsDD, 2017 – BuildingSmart Data Dictionary - http://bsdd.buildingsmart.org/. July 2017.

ISO, 2007 – ISO 12006-3:2007 - Building construction. Organization of information about construction works. Framework for object-oriented information. International Organization for Standardization, Oslo.

IFD Library, 2017 – National Institute of Building Sciences - https://www.nibs.org/?page=bsa_ifdlibrary. June 2017.

IFC, 2017 – BuildingSmart IFC - http://buildingsmart.org/ifc/. June 2017.

IFC, 2017_2 - BuildingSmart IFC overview - http://www.buildingsmart-tech.org/specifications/ifc-overview. June 2017.

ISO, 2013 - Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries. International Organization for Standardization, Oslo.

PAS, 2016 – BIM Level 2 – UK. http://bim-level2.org/en/standards/. June 2017.

NBSUS, 2017 - National BIM Standard. https://www.nationalbimstandard.org/. July 2017.

VA, 2017 - VA BIM Guide. https://www.cfm.va.gov/til/bim/BIMGuide/. June 2017.

COBIM, 2012 - http://www.en.buildingsmart.kotisivukone.com/3. November 2012.

uBIM, 2017 - https://www.buildingsmart.es/bim/gu%C3%ADas-ubim/. May 2016.

BIMServer, 2014 - http://bimserver.org/. December 2014.

CR_Handover, 2016 – CrossRail Learning Legacy – http://learninglegacy.crossrail.co.uk/documents/information-handover-principles/. January 2016.

EDMS, 2017 – EDMS Providers. http://www.edms.net/. June 2017

Crossrail, 2014 – The Crossrail Project - http://www.crossrail.co.uk/news/crossrail-in-numbers. November 2014.

Bentley, 2015 – Crossrail Bentley Academy - http://www.crossrail.co.uk/news/articles/crossrail-bentley-systems-launch-uks-first-dedicated-building-information-modelling-academy. February 2015.

AW, 2017 – Bentley Asset Wise - https://www.bentley.com/en/products/product-line/asset-performance/assetwise-alim. May 2017.

PICP, 2017 – Crossrail - Project Information Compliance Principles – http://learninglegacy.crossrail.co.uk/documents/project-information-compliance-principles/. March 2017.

BS_Open, 2017 – BuildingSmart Open Standards - http://buildingsmart.org/standards/technical-vision/open-standards-101/. February 2017.

NBS, 2015 – NBS Toolkit PDT - https://toolkit.thenbs.com/articles/pdts/. March 2015.

GoBIM, 2016 – CoBuilder – GoBIM - http://gobim.com/what-is-a-product-data-template/. May 2016.

Regulation EU, 2011 – Construction Products Regulation https://ec.europa.eu/growth/sectors/construction/product-regulation_en. 2011.

BSI, 2014 – COBie - https://shop.bsigroup.com/forms/PASs/BS-1192-4-2014/. 2014.

BSI, 2015 - Briefing for design and construction – Part 1 https://shop.bsigroup.com/ProductDetail/?pid=000000000030315621.

BSI, 2016 - Briefing for design and construction – Part 2 https://shop.bsigroup.com/ProductDetail/?pid=000000000030333121.

Veteran Affairs, 2010 – The VA BIM Object Element Matrix Manual.xls.

Crossrail_LL, 2017 – Learning Legacy - http://learninglegacy.crossrail.co.uk/. April 2017.

Cr_IA, 2017 – Crossrail Information Academy - http://learninglegacy.crossrail.co.uk/documents/information-academy/. February 2017.

Alhava, 2016 - Emotional intelligence—improving the performance of big room. eWork and eBusiness in Architecture, Engineering and Construction. Taylor & Francis Group, 6000 Broken Sound Parkway NW, Suite 300, Boca Raton, FL 33487-2742 CRC Press 2016, Pages 81–87.

Fulbright, 2013 - 9th Fulbright Litigation Trends Survey - http://www.businesswire.com/news/home/20130226005387/en/Fulbright%E2%80%99s-9th-Annual-Litigation-Trends-Survey-Litigation.

Gero, Tham & Lee, 1992 – Behavior: A link between function and structure in design. In D. C. Brown et al. (eds.), Intelligent computer-aided design (pp. 193-225). Amsterdam, Netherlands: Elsevier.

Sullivan, 1896 – The tall office building artistically considered. Lippincott's Magazine, 57, 403-409.

POP, 2017 - 4D POP Model Support for Lean Construction. https://www.researchgate.net/publication/233598401_4D_POP_Model_Support_for_Lean_Construction. June 2017.

ACIF, 2014 – Project Team Integration Workbook. Australasian Procurement Construction and Council, Camberra, Australia, Marsh 2014.

Applicant Organisation:

Fundación Laboral de la Construcción. Spain

Partners Organisation:

Asociación de Constructores Promotores de Navarra. Spain

Tipee. France

Sustainable Habitat Cluster. Portugal

Warsaw University of Technology, Civil Engineering Faculty, Poland

Preview Test: Evaluation Part 2 Module 1 (From 1.1 to 1.5)

Test Information

Description	This test will address to the contents from topics 1.1 to 1.5.
Instructions	It has the duration of 1 hour and it is composed by true and false questions as well as multiple choice questions, where only one is the correct.
Timed Test	This test has a time limit of 1 hour.This test will save and submit automatically when the time expires. Warnings appear when **half the time**, **5 minutes**, **1 minute**, and **30 seconds** remain.*[The timer does not appear when previewing this test]*
Multiple Attempts	This test allows multiple attempts.
Force Completion	Once started, this test must be completed in one sitting. Do not leave the test before clicking **Save and Submit**.

QUESTION 1

1. **The construction industry is a recognized leader on the adoption of innovations.**

True

False

1 points

QUESTION 2

1. **Integrated Project Delivery is only a type of procedure.**

True

False

1 points

QUESTION 3

1. **At a minimum, IPD must include tight collaboration between the owner, architect/engineers and contractors, from early design through project handover.**

True

False

1 points

QUESTION 4

1. **Nowadays BIM – Building Information Modeling is identified as being a fundamental part of IPD.**

True

False

1 points

QUESTION 5

1. **On an IPD process it is fostered the occasion of continuous changes.**

True

False

1 points

QUESTION 6

1. **Collaboration is one of the major components towards IPD.**

True

False

1 points

QUESTION 7

1. **Integrated systems means that all software used is interoperable.**

True

False

1 points

QUESTION 8

1. **An IPD process tends to maximize the contractor income.**

True

False

1 points

QUESTION 9

1. **The Strategic Definition stage is much more demanding on IPD processes.**

True

False

1 points

QUESTION 10

1. **IPD processes require a more detailed look to thermal comfort requirements.**

True

False

1 points

QUESTION 11

1. **The boundaries of the construction stages are the easier to identify.**

True

False

1 points

QUESTION 12

1. **The handover and close out stage does not demand any kind of information exchange in addition to the handover report sign on the site.**

True

False

1 points

QUESTION 13

1. **Communication is much easier if all agents talk in English.**

   ○ True

   ○ False

1 points

QUESTION 14

1. **A good methodology to share information is essential towards IPD.**

   ○ True

   ○ False

1 points

QUESTION 15

1. **Communication integration is achieved if all agents talk in English.**

   ○ True

   ○ False

1 points

QUESTION 16

1. **An IPD process in order to work properly must be developed in silos.**

   ○ True

   ○ False

1 points

QUESTION 17

1. **An IPD process in order to work properly must be developed in silos.**

   ○ True

   ○ False

1 points

QUESTION 18

1. **One of Integrated Information characteristics is being unique and reusable.**

   ○ True

   ○ False

1 points

QUESTION 19

1. **Product manufacturers need to change the way they share construction products information.**

   ○ True

   ○ False

1 points

QUESTION 20

1. **All information must be available for the design team at the Preparation and brief stage.**

   ○ True

   ○ False

1 points

QUESTION 21

1. **The most recognized definition of Integrated Project Delivery is the one presented by:**

   ☐ RIBA – Royal Institution of British Architects

- ☐ ISO – International Standardization Organization
- ☐ AECOO - Architects, engineers, contractors, operators and owners
- ☐ AIA - American Institute of Architects

1 points

QUESTION 22

1. **The standard addressed to Project Management is:**
   - ☐ ISO 12006
   - ☐ ISO 15686
   - ☐ ISO 21500
   - ☐ ISO 14040

1 points

QUESTION 23

1. **The use of an integrated project stages approach lead to:**
   - ☐ Process integration and systems integration
   - ☐ Process integration and integrated information
   - ☐ Integrated information and process integration
   - ☐ High-performing construction

1 points

QUESTION 24

1. **The most critical stage of the life cycle is:**
   - ☐ The early definition
   - ☐ The operation
   - ☐ The design
   - ☐ The construction

1 points

QUESTION 25

1. **One of the most used Classification Systems is:**
   - ☐ Omniclass
   - ☐ IFC
   - ☐ COBie
   - ☐ EDMS

Preview Test: Evaluation Part 2 Module 1 (From 1.6 to 1.8)

Test Information

Description	This test will address to the contents from topics 1.6 to 1.8.
Instructions	It has the duration of 1 hour and it is composed by true and false questions as well as multiple choice questions, where only one is the correct.
Timed Test	This test has a time limit of 1 hour.This test will save and submit automatically when the time expires. Warnings appear when **half the time**, **5 minutes**, **1 minute**, and **30 seconds** remain.*[The timer does not appear when previewing this test]*
Multiple Attempts	Not allowed. This test can only be taken once.
Force Completion	Once started, this test must be completed in one sitting. Do not leave the test before clicking **Save and Submit**.

Question Completion Status:

Save and Submit

QUESTION 1

1. **In order to achieve IPD the project team must be committed to collaborative processes and capable of working together effectively.**

True

False

1 points

QUESTION 2

1. **The Owner can delegate all their tasks in other agents.**

True

False

1 points

QUESTION 3

1. **On IPD processes the main commitment of the Owner is to spend as less as possible to get the built object.**

True

False

1 points

QUESTION 4

1. **To get an Integrated Team all roles must be identified as early as possible.**

True

False

1 points

QUESTION 5

1. **IPD agreements can be set only verbally because all parts trust each other.**

   True
   False

1 points

QUESTION 6

1. **One of the most common obstacles on setting IPD teams is the ability to work with new processes.**

   True
   False

1 points

QUESTION 7

1. **On IPD processes the owner must be available to invest in training actions for the project team.**

   True
   False

1 points

QUESTION 8

1. **After the Design stage, the Owner can leave the project team.**

   True
   False

1 points

QUESTION 9

1. **On an IPD process the Contractor must take part of the team only during the Construction stage.**

   True
   False

1 points

QUESTION 10

1. **IPD requires much more information exchange and coordination from the design team.**

   True
   False

1 points

QUESTION 11

1. **During IPD project the project team must belong to a new organization, the project.**

   True
   False

1 points

QUESTION 12

1. **IPD projects foster the same agent to be involved in more than one project.**

   - True
   - False

1 points

QUESTION 13

1. **On IPD process there is no margin for errors.**

   - True
   - False

1 points

QUESTION 14

1. **Delivering high-performance begins with the effort to understand and define the purpose of the object to be built.**

   - True
   - False

1 points

QUESTION 15

1. **Life cycle cost is not considered in IPD processes.**

   - True
   - False

1 points

QUESTION 16

1. **On IPD processes the metrics should be geared for cost and schedule evaluation.**

   - True
   - False

1 points

QUESTION 17

1. **On IPD processes the metrics should be geared for cost and schedule evaluation.**

   - True
   - False

1 points

QUESTION 18

1. **On IPD processes the evaluation of surrounding impacts is important for the measurement of the project success.**

   - True
   - False

1 points

QUESTION 19

1. **Cost and schedule metrics are the most important for the success of an IPD process.**

- True
- False

1 points

QUESTION 20

1. **The measurement of an IPD process should address to the Project performance, Project organization and Process metrics.**

- True
- False

1 points

QUESTION 21

1. **One of the essential aspects for building an Integrated Team is:**

- The agents CV
- The friendship with the owner
- The technical competence
- The proximity of the offices to the site

1 points

QUESTION 22

1. **To foster the project team engagement toward IPD a Owner must:**

- Set tight contractual terms
- Provide training actions
- Be present in all stages and lead the process
- Hire competent agents and let them work

1 points

QUESTION 23

1. **A high-performance built object must be:**

- Operable
- Beautiful
- Expensive
- Full of sensors

1 points

QUESTION 24

1. **One of the core tasks of a facility development and operations team is:**

- Build the cheapest object that is possible
- Balance construction costs and schedule to deliver quickly the object

- Identify all the clients goals and objectives
- To develop the most the off-site construction

1 points

QUESTION 25

1. **One of the most common procedures used in public procurement is**
   - IPD
   - Multi-prime
   - CM at Risk
   - Design Bid Build

Co-funded by the Erasmus+ Programme of the European Union

Continuing V.E.T. Training Programme in Lean Construction

ERASMUS+ Programme
Key Action 3 | Call 2016
Support for Policy Reform
Support for small and medium sized enterprises engaging in apprenticeships

Project Code:
2016-1-ES01-KA202-025694

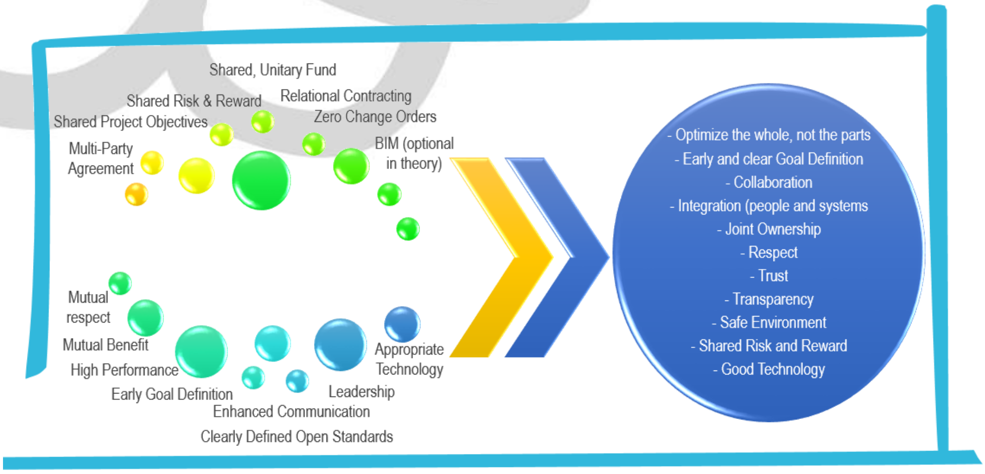
Partnership:

- Fundación Laboral de la Construcción (Spain).
- Asociación de Constructores y Promotores de Navarra (Spain).
- Technological & Innovative Platform for Environmental Efficiency –Tipee (France).
- Cluster Habitat Sustentável (Portugal).
- Warsaw University of Technology, Civil Engineering Faculty (Poland).

2. IPD - INTEGRATED PROJECT DELIVERY

Activity 1 – IPD Principles (1 hour)

Considering with your experience and context, develop a sequence, according with IPD present framework, from the easier to the more difficult component to be achieved towards IPD in your reality. Justify the reasons of the defined sequence (between 200 and500 words).



SEQUENCE

JUSTIFICATION

(200 to 500 words)

Activity 2 – POP Model Framework (2 hours)

Considering what you have learn regarding the development and organization of the POP model framework, develop for a simple construction work (example of a dwelling where you are the owner) the requirements you would place for the Design and Construction POP and Operations & Maintenance POP.

Activity 3 – Measurement of Integrated Project Outcomes (1,5 hours)

Assuming the base contents from the developments made during Activity 2, develop a framework for the measurement of project outcomes in some aspects.

The results must include the structure of the measurement, the topic to be measured as well as the schedules, agents and examples of the developed measures.

Recommendation: Use the project stages and select some aspects/decisions evaluated presented on Table 8.

Applicant Organisation:

Fundación Laboral de la Construcción. Spain

Partners Organisation:

Asociación de Constructores Promotores de Navarra. Spain

Technological & Innovative Platform for Environmental Efficiency –Tipee. France

Cluster Habitat Sustentável. Portugal

Warsaw University of Technology, Civil Engineering Faculty, Poland

Co-funded by the
Erasmus+ Programme
of the European Union

Continuing V.E.T. Training Programme in Lean Construction

ERASMUS+ Programme
Key Action 3 | Call 2016
Support for Policy Reform
Support for small and medium sized enterprises engaging in apprenticeships

Project Code:
2016-1-ES01-KA202-025694

Partnership:

- Fundación Laboral de la Construcción (Spain).
- Asociación de Constructores y Promotores de Navarra (Spain).
- Technological & Innovative Platform for Environmental Efficiency –Tipee (France).
- Cluster Habitat Sustentável (Portugal).
- Warsaw University of Technology, Civil Engineering Faculty (Poland).

2. IPD - INTEGRATED PROJECT DELIVERY

Workshop (3 hours)

Scope: The workshop aims the discussion of several issues related with the module, as well as the discussion of the work developed on the 3 activities.

Just for consideration it is foreseen the following schedule:

15 min. – Brief overview on the topic, relevant aspects, issues that cause more confusion.

45 min. – Discussion of the 1st activity

45 min. – Discussion of the 2nd activity

15 min. - Break

45 min. – Discussion of the 3rd activity

15 min. – Other issues to be considered or discussion of the previous topics.

Applicant Organisation:

Fundación Laboral de la Construcción. Spain

Partners Organisation:

Asociación de Constructores Promotores de Navarra. Spain

Technological & Innovative Platform for Environmental Efficiency –Tipee. France

Cluster Habitat Sustentável. Portugal

Warsaw University of Technology, Civil Engineering Faculty, Poland