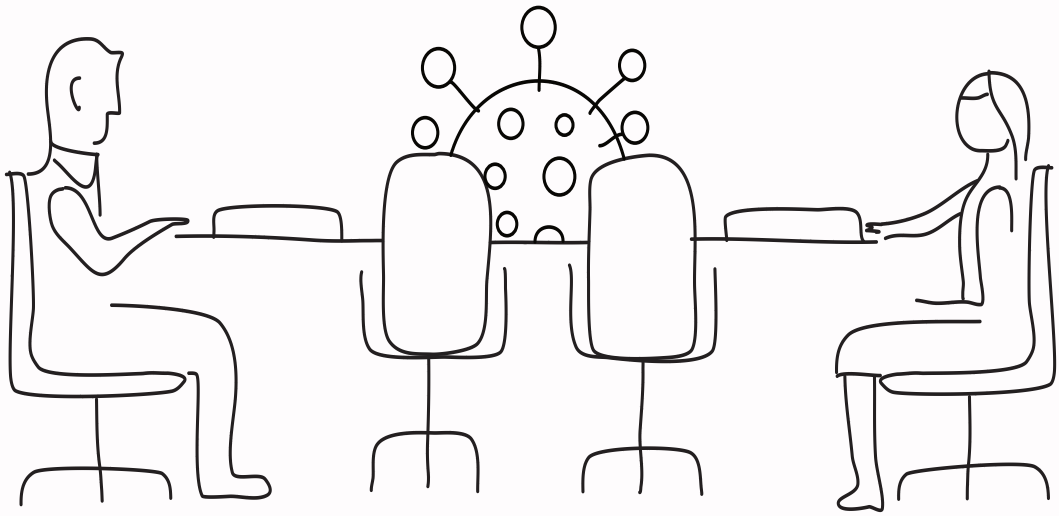

Accelerating the Evolution of Design Management in Construction
The COVID-19 effect

buildoffsite

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Publisher

Buildoffsite is a membership organisation with members from a wide range of UK and international client, supply, professional services and academic organisations.

Buildoffsite is a UK-based business organisation that promotes:

- Increased use of offsite methods across all sectors of the UK construction market;
- Innovation in the development of offsite solutions;
- More effective promotion of business and project benefits by offsite solution suppliers;
- Improved understanding by clients and suppliers of the benefits of offsite solutions;
- Education and skills development in the use of offsite solutions;
- Debate, discussion and knowledge transfer relating to the use of offsite solutions.

Mission

Buildoffsite's mission is to be the trusted, independent voice of the UK construction industry with respect to offsite and pre-manufacturing, and to provide all relevant support to our members and other stakeholders to enable them to feel confident to promote and adopt the same.

Vision

A permanent, positive, transformation of the UK construction industry – enabled through the increased adoption of offsite and pre-manufactured solutions to drive increased productivity.

CIRIA

The Construction Industry Research Information Association is the organisation that underpins the Buildoffsite organisation.

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Executive summary

It is clear that the COVID-19 pandemic has changed the way we work, with a significant number of those interviewed for this study reporting an increase in home or remote working and collaboration with teams from different locations, utilising skillsets that would previously have been limited by location.

There is a significant argument that it should change the way we build too. Delivering reliability, predictability and reducing time on site, offsite construction and modern methods of construction (MMC) are more important than ever, and it is essential that design teams and offsite manufacturers are better able to take advantage of this.

With increasing numbers of team members working from home, the office environment needs to become a space that translates to the home. This can be supported by the provision of computers and office furniture, while the facility of the office workplace remains available in a socially distanced arrangement for those who cannot work from home, for round-table meetings where required, and to house significant computer processing facilities. This focuses on the equipment aspect of an office environment, but it is also notable that workplaces provide a space for support, mentorship and contribute to social wellbeing. There is a need to replicate this too, when considering remote working, with informal team check-ins one possibility to do so.

Well defined requirements become crucial to ensure all design team members, stakeholders and suppliers are working to a common goal. This begins with the brief for design teams, which should be detailed to the individual roles each employee will fill and their responsibilities and crucially their deliverables (e.g. models, specifications, test plans and results, etc). This improves productivity by providing guidance from the outset, reducing the time spent in virtual meetings to answer questions, of particular support for more recent recruits and trainees. A video library will also prove useful to provide training by topics and could be equally useful in remotely briefing construction sites.

The need to specify is paramount not only to the team members, but to the work package as a whole. A Systems Engineering-based approach to the design management process facilitates a clear process of decision making, including where changes are required. Supported by a Quality Function Deployment approach to defining requirements, the team are able to make individual but compatible decisions within one consistent framework, always guided by the client's preferences.

Improved communication from manufacturers and understanding by design teams of the opportunities for MMC and associated dimensional tolerances would be of significant benefit, particularly if MMC suppliers' manufacturing capabilities were catalogued, so that teams may take full advantage of them from the design stage, reducing the need for manufacturers to reverse engineer.

Just as the office environment has been challenged by COVID-19, so too has the construction site. Social distancing, one-way systems and sanitisation stations are more easily implemented in factories producing offsite modules and components, than on traditional construction sites, where operatives move between areas. In a factory environment, an operative can remain in one position on the workflow. Design for Manufacture and Assembly makes MMC and offsite construction more accessible to design teams and work packages. It is time to take greater advantage of these.

5 key observations:

- Communication is key between colleagues, stakeholders, clients and manufacturers to fully realise the benefits of offsite and MMC. An integrator becomes a crucial role.
- Libraries and catalogues provide helpful remote access to knowledge and understanding, including video tutorials and technical specifications.
- Designing to take advantage of existing offsite and MMC capabilities will yield far greater cost and time benefits than applying these opportunities retrospectively.
- Individual skillsets and expertise can be deployed irrespective of location, enabling teams to be arranged by skillset and compatibility for improved productivity and outcomes.
- Offsite construction can offer reliability and continuity even in challenging circumstances.

5 key actions:

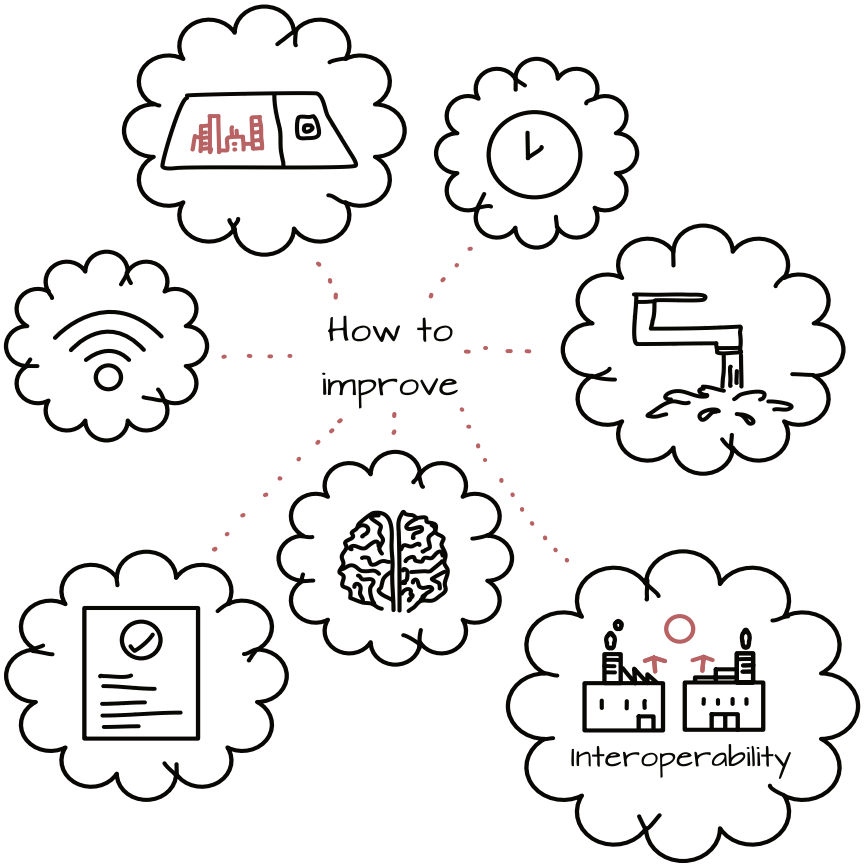
- Ongoing mentorship and training should be considered in order to fully develop and utilise a team's capabilities and support their wellbeing.
- Improved understanding of tolerances and capabilities of MMC suppliers would help design management teams to better utilise opportunities.
- The ability to provide real-time design updates and sketches needs to be better utilised in the virtual setting.
- Increased compatibility (interoperability) between components manufactured offsite would enable wider and more flexible use throughout the construction industry.
- Adopting a Systems Engineering based approach for decision making will enable team members while working remotely to make consistent decisions within a wider work package.

Introduction

It is going to take us a while to get through the COVID-19 pandemic, but we can already see changes and opportunities for further improvements in how we work. This report is the result of research carried out in August and September 2020. It was initiated as it was clear that whilst people and businesses were adapting to the new situation, some aspects were working better than others. Some people had found solutions whilst others were still looking and experimenting.

The research has focused upon remote working, how tasks are defined and changes managed. The aim being to suggest ways that design management processes in construction may evolve.

Opportunities to learn from each other and from other sectors were beginning to become apparent. Here we aim to highlight the learning and several approaches from other sectors, which may help us further.



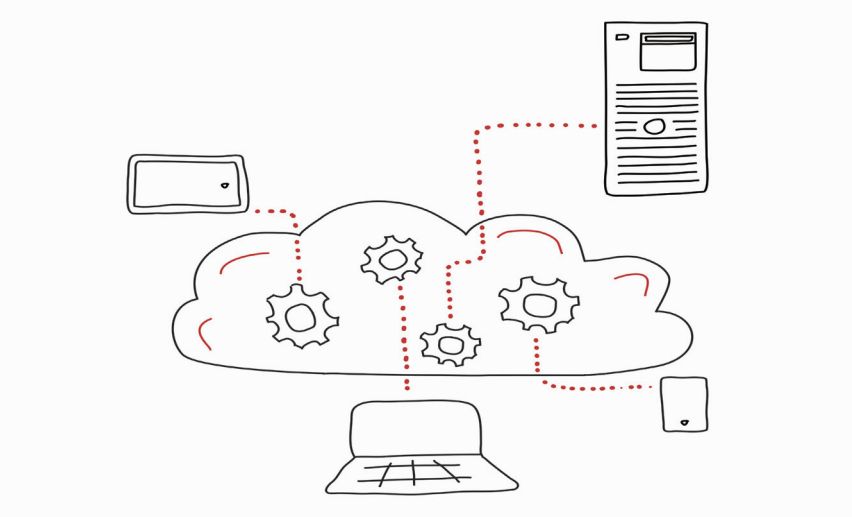
Methodology

The study has involved an online survey, a series of individual interviews and two round table discussions. There has also been a review of related academic papers. The survey was widely distributed and open to anyone involved in the construction design process. The individual interviews and round table sessions were mainly with business leaders or experts in BIM-based workflows. Views of younger and less experienced staff have also been sought, although they are less well represented amongst the 45 contributors.

1 Main findings

Impact on jobs

68% of online survey participants reported a move to only working from home, with 12% furloughed, 12% reporting no change and 8% noting a change to increased home working. There was also a site closure resulting from a COVID-19 outbreak on site. This is more an indication of how the contributors were impacted rather than the sector as a whole. For example, several contributors indicated that their less experienced colleagues were the majority of staff being furloughed.



What has gone well?

Overwhelmingly, participants reported a positive opinion of how the sector had adapted to the challenges of the coronavirus pandemic. Many reported feeling that they were more efficient and productive working at home, as interruptions and unproductive times, such as travel time, were drastically reduced, and could instead be used more productively to complete tasks. However, as explained in the next section, this was dependent on the home environment.

The coronavirus pandemic period appears to have been a driving force to accelerate change in the sector. Often these changes were already in the pipeline – for example, moving to more flexible ways of working and cloud-based platforms, and video conferencing, but the need to work from home meant that these initiatives were implemented much more quickly. Collaboration and innovation have been key to finding solutions to the challenges of working remotely.

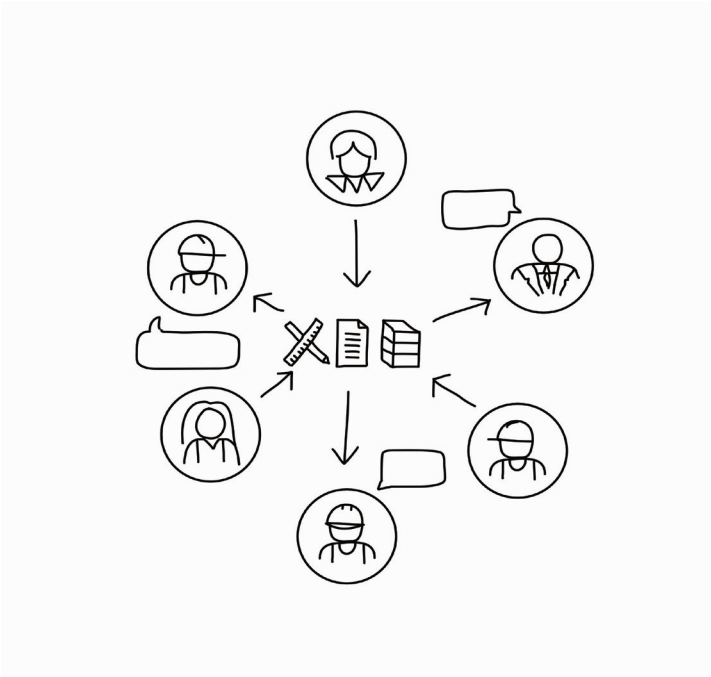
Teams quickly adapted to holding online meetings, with Microsoft Teams being the most commonly used platform. 20% of participants in the online survey reported communication with colleagues as being one of the biggest successes during this period. In the online round tables, a participant from a company with regional offices said that the change in ways of working had made them feel more like a part of a wider team.

Furthermore, it was reported that companies were utilising their expertise more efficiently. Where previously staff had worked in regional teams, there had been a shift to choosing staff from across the regions to work in teams according to their skillsets. Companies had databases of staff competences, but they were not being used as widely before the pandemic.

It was relatively easy to link home based-computers to more powerful machines back in the office via a Virtual Private Network (VPN), where processor intensive work was needed for rendering etc. Using VPNs also had the advantage of providing similar levels of confidentiality and security that is available on office-based machines. The online survey revealed that 75% of participants had access to BIM when working remotely. It was noted that often it was the younger staff members who had come up with solutions to challenges surrounding the use of IT.

Most participants said they felt they would not go back to using offices as they had done previously. Instead, they felt they would continue working from home and use office spaces when face to face contact was needed.

What has needed, or needs, improvement?



Whilst 56% of participants in the online survey felt that the use of IT had been a success during the pandemic, it remained a challenge for certain tasks.

Exchanging and commenting upon concept designs without having traditional tracing paper sketches to overlay, for example, has been challenging. Many of those involved in the design process report not yet having found an 'ideal' alternative to sitting around a table and discussing drawings. It highlighted a need for a tech solution to support real-time drawing and sketching in online meetings.

The challenges of working from home were also highlighted, with balancing work and home life being a commonly reported issue, and 30% of online survey participants reporting a decrease in productivity. Home schooling led to exceptionally long days for some staff as they tried to fit work around their home education commitments. Others reported a blurring of work time into home life because, without a structured day in the office, it was easy to work later into the evening and colleagues often expected people to be available for online meetings, because they would be at home.

In the earlier months of the pandemic, participants reported busy diaries with back to back meetings, which made it hard to get work done. There was a perception from younger staff that it was assumed that all staff found lots of video meetings equally tiring. However, one interviewee pointed out that younger staff seemed less concerned by this, perhaps because they were already used to spending time video calling with friends in their personal lives before the pandemic hit.

Home working also brought concerns surrounding the living environment of different people. Some staff who were in shared accommodation did not have access to a desk space, for example, and were trying to work in crowded environments.

Time previously required for commuting has been used as work time by some contributors. Some missed the transitional, personal, time between home and work that commuting provided. Individuals will need to decide how they consider the gained time when they would have previously been commuting when working from home and colleagues will need to learn to respect their choices.

Isolation and lack of face to face interaction for those living alone was also a concern, particularly from a wellbeing and mental health point of view. Many participants reported taking an active approach to checking in with staff and colleagues over this period, and some had opened up office space specifically for those who lived in situations that made it very difficult to work from home.

Difficulties in selecting new recruits, and with training and mentoring junior staff, were also highlighted. Without the office environment, it was more difficult for managers to be available to guide and train their staff, in a sector that ordinarily provides a lot of 'on the job' training.

It was also difficult for managers to assess the strengths and needs of newer members of staff. Conversely, those members of staff whose poor performance in an office-based environment was compensated for by colleagues became more evident when they had to work more independently.

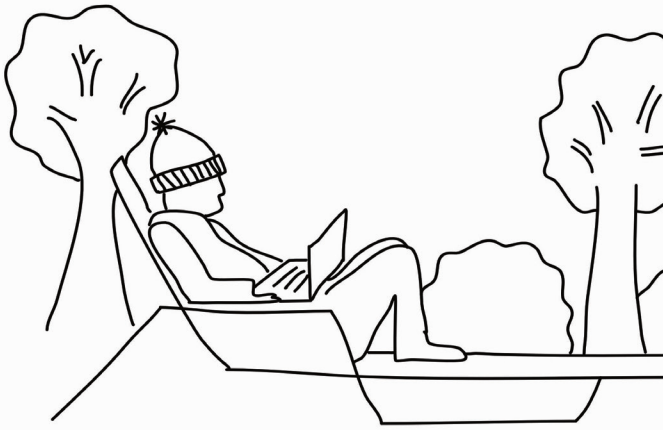
Remaining challenges & potential solutions

2

Working away from the office – or not

Although the limitations of trying to discuss drawings and sketches virtually were consistently identified as a challenge in the design management process, some useful solutions were shared.

The use of BIM 360, ProjectWise 365 and the online collaborative whiteboard platform Miro were all identified as being helpful tools to address this issue. Another possible solution was found in the use of graphic tablets, which made drawing on a tablet with a stylus feel more similar to drawing on paper.



Some companies are now considering moving to using these more often, using graphic tablets such as those made by Wacom. Basic models show the image on the computer screen, whilst more expensive models provide the image on the graphics tablet as well, which is probably more useful when a conference call is in progress and screen space is being used for several purposes. There are other online platforms and graphics tools available, but those above were mentioned in the survey and other contributions to this project (they are not product endorsements by Buildoffsite).

The limitations and variations of the home environment also pose a challenge. Some homes are more easily adapted to accommodate home working than others. Some households do not have childcare considerations, and of course some will have children returning to school. Whilst these pressures are difficult to solve, several solutions to space and work environment issues were suggested.

Firstly, managers can ensure that their team have access to an appropriate workspace, as they would in the office. This could simply be by providing office equipment like desks, task lights and appropriate chairs. Secondly, for those with no feasible way to create a suitable home working environment, some participants had opened the office to them with strict COVID-19 safety measures in place. If staff felt they could not work from home, they had the choice to use the office in a socially distanced manner instead.

New recruits, young professionals and mentoring

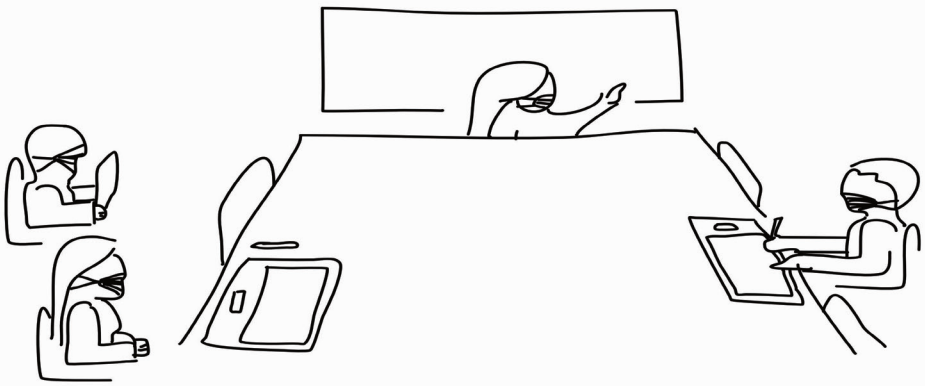
One participant explained that they had not yet met any of their current project team in person, which made it difficult to instinctually recognise voices on group calls and be familiar with skillsets and areas of expertise.

Many others noted the difficulty they had in keeping newer recruits ‘on track’ and that questions, which in an office setting would’ve been a brief conversation over their shoulder, now required online meetings. There was less opportunity for continuous feedback and guidance.

This suggests that there may be ways of improving task briefing for remote working. Indeed, some participants had found solutions to this by creating much more detailed briefs, ensuring every person was clear on their specific role and tasks to complete, along with worksheets to track progress. Others used weekly team meetings for this purpose. Many managers reported increasing their use of one-to-one calls with their team members. Elements of the Systems Engineering toolkit could probably help here, see ‘Ideas for future process innovation’ section below.

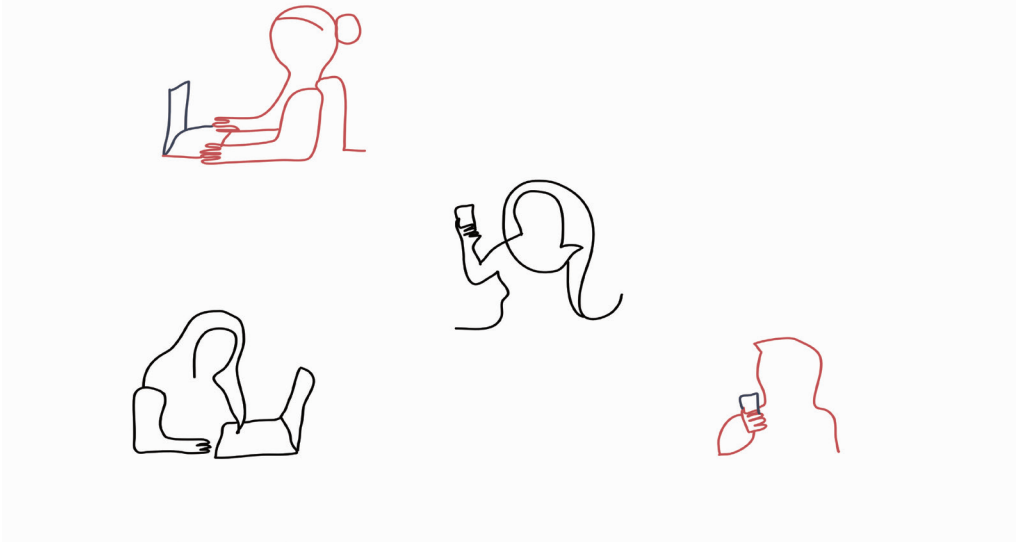
The challenge of replicating ‘on the job’ training within an online office environment was widely reported across interviewees and round table participants. Many formal training courses have also been put on hold due to the pandemic. There was consensus that ‘on the job’ training was difficult to replicate in this new environment, however, one interviewee proposed an innovative solution to this.

Their company was producing a series of ‘how to’ video guides. These ensured that even if a member of staff was unable to demonstrate something in person, everyone on a site could see exactly what was required. These video guides could be produced for virtually any scenario and provide a catalogue of resources to be drawn upon in the future. There is a case study on these video guides in the Appendix.



Intra-project team communications

Keeping the team informed



Microsoft Teams was the most widely used platform for online meetings and participants reported an 'online meeting etiquette' evolving over recent months, which helped to resolve early issues with back to back or sometimes unnecessary meetings, along with helping the meetings themselves flow more naturally.

Most people spent between 20% and 60% of their time talking to colleagues, partners, stakeholders, clients and contractors. In some roles this rose to as much as 85% of their day. The majority of this time was taken up with group video meetings, with a smaller proportion of time being spent on one-to-one calls.

Early on there was a tendency to convene meetings for design decision making – this reduced over time, but the need for regular wider team briefings was recognized. As highlighted above, numerous companies began kicking off the week with these sessions to ensure everyone knew what was expected to be achieved by whom during the coming week.

Most communications around changes to design requirements were made first by a telephone or video call and then confirmed by email but few indicated formal systems for this. Change management is discussed in the section on configuration management below.

Specifying work packages

The survey has revealed that most tasks were either defined by activity (32%) or deliverable (32%). 16% of tasks were defined by time, 12% by the required performance, 4% by the required fit and 4% by boundary, interface conditions or requirements. This is significant when it comes to working remotely, where co-ordination is key to successful delivery and could be an area where further productivity improvements could be made.

In other industries, where there are integrators of complex products and suppliers of sub-systems with proprietary intellectual property, work packages tend to be described in terms of deliverables (specifications, BIM objects and models, test plans, test results etc.), interfaces and performance. This enables complex projects to be delivered with a large degree of autonomous design activity within supply organisations.

In product-based sectors, initial concepts are developed based upon clear understanding of clients' preferences. This is also the case in the construction world but largely in a less systematised manner. Elsewhere these preferences are commonly based upon marketing (client) led multi-variable trade-off analyses, which permit numerous concepts to be evaluated quickly.

One method of doing this is known by the term QFD (Quality Function Deployment) or "The House of Quality", due to the format that the data is analysed in. This has been used by a major construction sector client in the past, so there are grounds for believing it could help here. The forthcoming government sponsored Value Toolkit should also help to ensure that the customer's needs are clearly connected to the definition of individual work packages in a consistent manner.

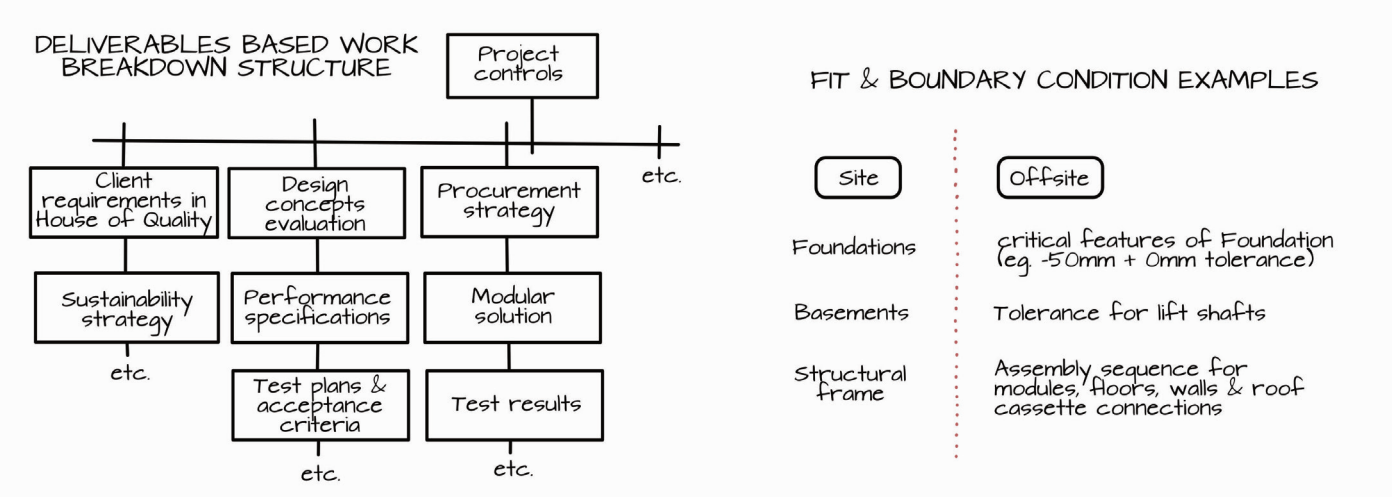
The advantage in this context is that individuals working remotely would have a framework for decision making that would help ensure they stay aligned with the decisions being made by others in the team. Aspects that define the quality of the product can be cascaded down through subsequent levels of detail that provide a basis of design, which can be directly linked back to the client's preferences. More information is provided on this in the appendices.

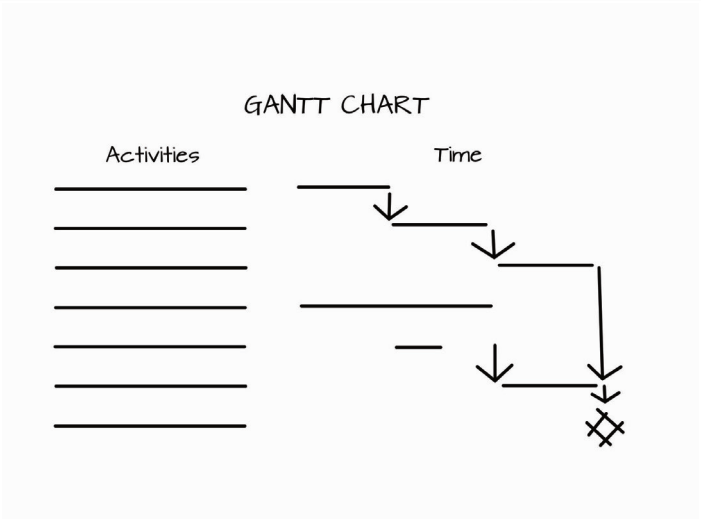
General advice in the survey concluded that to get the most from offsite work packages we need to:

- Provide complete specifications, no imponderables.
- Provide more commonality of components between different offsite providers.
- Look at the benefits and adaptions of offsite to meet the builder's requirements.

The interviews indicated that:

- Project managers need to be better informed on offsite options and methods.
- Quantity surveyors want more offsite products to be interchangeable.
- Clients want more knowledge of the market offerings.





Managing meetings

The survey, interviews and round table discussions all indicated that design teams have been spending a lot of time in virtual meetings. However, the survey was encouraging with respect to creativity.

- 84% of people felt they had time for being creative and problem solving.
- 72% of people felt they had enough time for creative interactions with others.

The time saved by not travelling to physical meetings was almost universally appreciated, however the ability to present and explain concepts to clients (in particular) is still perceived to be important.

Quick wins from the survey include:

- More sharing and drawing software to make it possible to draw in real time on a video call and share these drawings.
- Time management improvements to spread meetings so that they are not back to back.
- Start communications with contractors at an early stage in the project and keep communications regular throughout to ensure it stays on track.
- Ensure all employees have good internet connections at home.

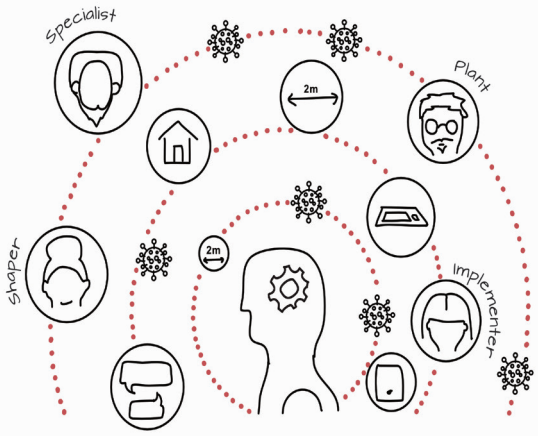
A key task going forward is to adopt methods of working that reduce the number of meetings and the range of participants involved. Work packages at all levels, from major contracted packages to individual project team members' work allocations, need to be defined in terms of deliverables and associated quality aspects. Wherever feasible, performance-based specifications for the outputs will provide team members with scope to work without recourse to avoidable meetings.

Video conferencing requires greater data bandwidth so voice-only conference calls have proved to be more reliable for home workers.

It is becoming apparent that running meetings with a group in a room and others remote can be more challenging than either when all are present or all remote. Holding meetings with all participants on-line can be easier. However, cameras in offices can be problematic too and so more private spaces for individuals on conference calls may be called for. It has been suggested that corporate logos are used for backgrounds to help place who people work for and avoid unprofessional or unintended backdrops. (This can be done electronically in several on-line meeting platforms).

Team member selection

The make-up of teams posed both benefits and drawbacks during the pandemic period. The regional format of some teams was replaced with an approach considering the skillsets of all company employees, regardless of their physical location. This had advantages in utilising expertise and skillsets across the company in a more productive way. Although companies had this information prior to the pandemic, remote working encouraged them to use this in a new way.



However, challenges with team member selection were also highlighted. It was widely reported that, when interacting virtually online, body language and non-verbal communication is often missed. Some felt it hard to 'get to know' colleagues they hadn't met in person. Others explained that working from home had been easy to adapt to whilst they were in project teams that had existed prior to the lockdown period, but thought it may be more difficult to start new projects with unknown colleagues when working remotely.

Managers also noticed that it was sometimes difficult to recognise both high and low performance when working remotely, as well as getting to know someone's strengths and weaknesses in their role. More frequent one-to-ones could help address this. Where new teams are being assigned, psychological profiling, for example the Belbin Team Inventory (taken with an understanding of the limitations), could help create cohesive teams with a range of strengths that gel together.

It was widely acknowledged that 'office chat' provided an opportunity to get to know colleagues, building relationships and trust, and that there was a need to replicate this in the new world of working from home. To overcome this, one manager had set up weekly social calls with their team. The call including the whole team and was purely for the purpose of replacing this informal, 'non work' social interaction that they would have had in the office.

Teams could also consider whether they could replicate their former social interactions online. For example, holding 'pub quizzes' on Microsoft Teams (or similar) or hosting 'virtual away-days'.

The role of the office in future

There is much uncertainty regarding the office of the future. Employers, architects and developers are all giving this considerable thought at this time. It is however clear that the requirements are changing.

For the design team it has been demonstrated that day to day operations can be managed with significant home working. That said, offices will need to provide:

- IT infrastructure, communications, servers, larger processors
- More, larger meeting facilities for socially distanced events (meetings, pitches, training, war rooming etc.)
- Socially distanced desks, both 'hot desks' for home workers and permanent desks for those who cannot work from home
- More mental health support to employees
- Improved cleanliness and hygiene standards in workplaces.

A case study of how a medium sized architectural practice in London is envisaging change is provided as a case study in the appendices.

3 Ideas for future process innovation

This section includes several aspects that may help us manage in both the COVID-19 and post pandemic period.

Configuration Management

COVID-19 working has highlighted the need to ensure that people working remotely have clear boundaries to design within and that changes to these are rigorously controlled. Once a general concept has been agreed upon and work starts to refine it, the major packages can be defined and a form of change control called "configuration management" can be applied to them. As mentioned in the interviews, the RIBA Plan of Work 2020 Stage 3 Spatial Design has moved in this direction. It states "Initiate Change Control Procedures".

In this context Configuration Management is the process for establishing and maintaining consistency of a design package output's performance, functional, and physical attributes with the requirements of the rest of the project.

The ISO has published a standard that describes this in detail. "ISO 10007:2017 provides guidance on the use of configuration management within an organization. It is applicable to the support of products and services from concept to disposal". The bibliography to this report includes several peer-reviewed papers that report on how this may be applied to construction. Dimensional tolerances are a key aspect of this, particularly when it comes to managing onsite and offsite design interfaces.

In other sectors this would typically be done by the design leadership within a "Systems Engineering" based approach (see below). That defines packages (the facility, assemblies, major parts etc.) as configuration items and any changes to them need to pass through a technical and (if appropriate) commercial change authorisation process.

Dimensional tolerances

In the survey, overall, both where performance of what is being designed and where fit of what is being designed was required, 46% of respondents referred to industry standards for tolerance ranges. This is potentially an issue as modern methods of construction (MMC) can have different requirements to traditional construction.

The current BS 5964-1:1990, ISO 4463-1:1989 "Building setting out and measurement. Methods of measuring, planning and organization and acceptance criteria" is 30 years old and currently under review. It is important that a revised standard recognises the need for onsite/offsite interface tolerances (foundations to modules, modules to modules, floors to pods etc.).

Modern manufacturing methods are capable of reducing or eliminating the need for complex adjustable fittings or even the use of "secondary" steel frames. Manufacturers need to communicate their capabilities to designers, who need to design to exploit improvements to deliver better value to clients. Buildoffsite's case studies have previously illustrated how this may be done.

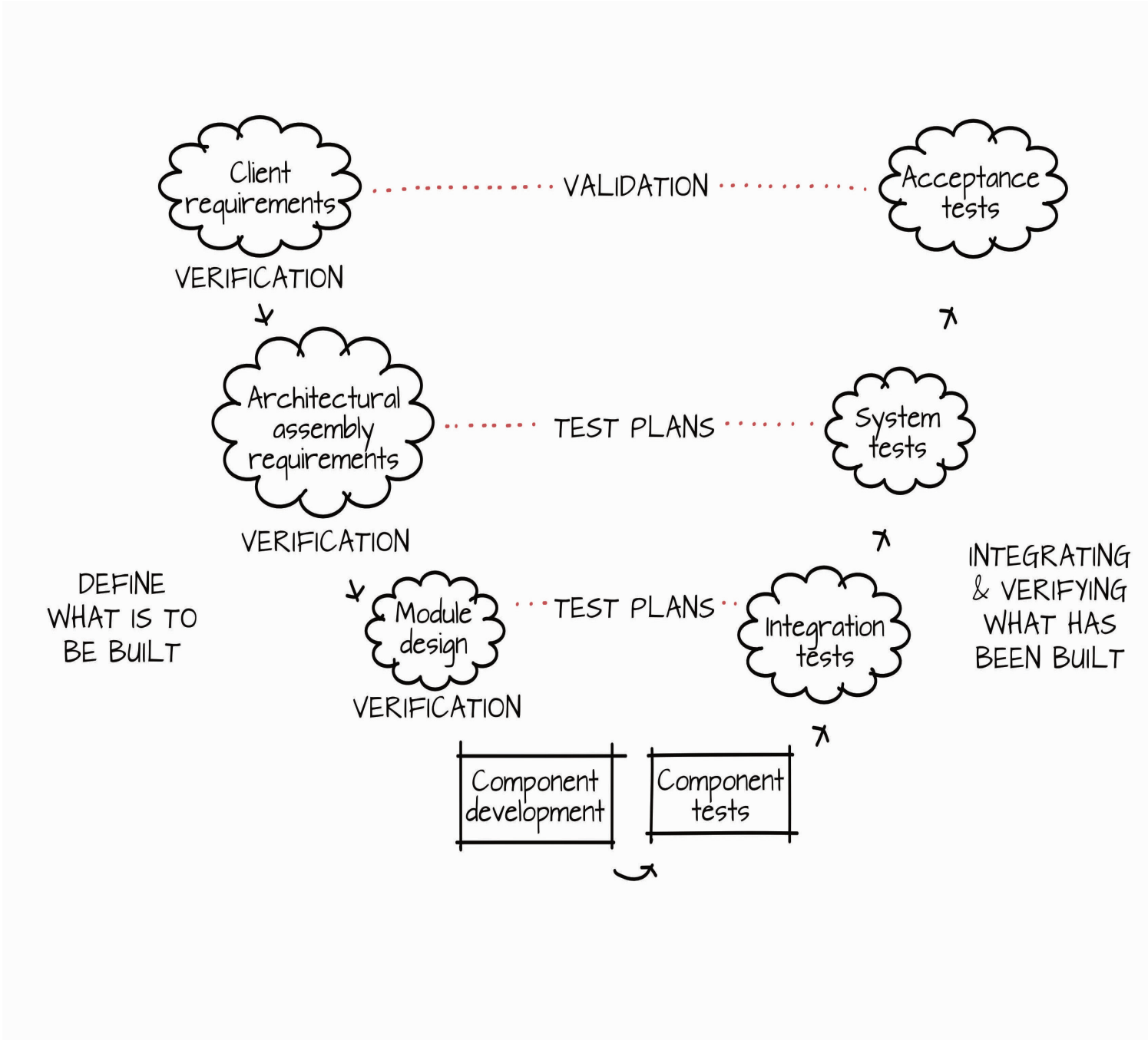
75% of survey respondents had access to BIM, with 14% working in 2D, 32% in 3D and 54% a mixture of the two. 71% use BIM for dimensional tolerance compatibility with Navisworks being mentioned by interviewees for clash avoidance purposes. However, a significant proportion of respondents did not use tolerance analysis in their BIM models.

In the COVID-19 era, with more remote working, design co-ordination using traditional methods has become more challenging. BIM platforms and other 3D CAD systems have capabilities to facilitate and, to varying degrees, automate tolerance management.

A Systems Engineering approach to design

By defining the performance requirements, interfaces and boundary conditions as well as timing and any specific components, materials and finishes to be used, suppliers may be tasked with developing their part of the design without the need for large and regular meetings with members of the wider project team. This approach could significantly improve productivity in the construction design process, but it would typically need individuals or organisations to develop the integration and coordination role beyond current practice.

The figure below summarises the systems engineering approach using a well-established "V" diagram. Here it has been adapted for the construction sector. The process starts at the top of the V and descends down the left-hand side before progressing up the right-hand side. Note that the steps define tangible deliverables at each stage.



In this way, multiple suppliers are able to deliver significant sub-parts of the design, associated test requirements, test results and assemblies, ultimately delivering a complete, complex facility or building.

With the technology trend towards platform-based approaches and offsite manufacture, this methodology is becoming ever more relevant to design for construction.

Designing without creating barriers to MMC

There has been much discussion of having a level playing field of late. In this context there are potential benefits from designing with a presumption of exploiting modularity (in any of its forms). Designing building grids that are suitable for either MMC or traditional methods is just one aspect.

In general, MMC providers have designed systems to address many issues, whether they relate to foundations or roof drainage, feasible spans or transport restrictions. By taking designs to too great a level of detail pre-tender, there is a real risk of excluding these validated designs and losing some of the benefits of using MMC. The Buildoffsite publication "Your guide to specifying modular buildings" could help, as would greater understanding of suppliers' manufacturing capabilities and cost drivers for the types of systems you are interested in exploiting.

Designing to a more detailed level pre-tender is likely to result in the potential MMC suppliers having to reverse engineer as well as price a bid during a relatively short tender submission period and submitting "non-compliant" bids as alternatives. This represents a lot of wasted activity that could be avoided if a more generic design were to be used for tendering, or with greater, earlier, use of requests for information (RFIs) from MMC suppliers to understand how to get the most out of MMCs. With increased home working, centrally held information of this type needs to catalogued and access to it facilitated.

A new approach to procurement to unlock productivity improvements

Standard forms of construction contract are becoming more supportive of collaborative project delivery. However, several lessons that could be adopted from other sectors include:

- **The integrator role**

Neither clients nor tier 1 contractors generally (with the exception of the power generation sector) currently have the role of integrator as seen in other industries. The ability to manage supply network tolerance allocations (performance of deliverables and dimensional attributes), configuration changes, authorisation (or rejection) of concession or derogation requests (e.g. variations from the specification or delivery timing) whilst maintaining the integrity of the overall design and project plan is fundamental to working differently. Change management should not primarily be driven by commercial compensation event processes. Many changes do not need to impact the commercial outcome, although some will.

- **Supplier development programmes**

The Supply Chain School has been considering this subject for a while. It plays a major role in many sectors. Construction tends to work from project to project. Main contractors often have their regular suppliers but some lower tier suppliers refuse to work for the same main contractor on consecutive projects. Major clients may have framework contracts that last for several years.

But while there is a lot of competition to win a project or a framework, once appointed there is little activity to address weaknesses in the winning parties. Other sectors have developed approaches that push performance (and productivity) improvement relentlessly, year on year. This should be an opportunity for the construction sector too.

- **Supplier performance management**

Linked to the above, supplier performance management could move on from the traditional cost, time and quality triumvirate and consider ways of collaboratively improving performance at all levels of the supply network.

Good supplier development programmes create a more transparent business environment. In this context it is important that positive behaviours are encouraged and negative ones discouraged. This can involve "pain and gain sharing" contracts. It may include lean construction/offsite maturity assessments or the like. This will provide more visibility of what is going well and not so well on site. Consequently, it probably also needs a rethink on how 'disallowable costs' are dealt with. We often learn from mistakes so penalising the first time an avoidable cost is incurred may not be constructive and is likely to encourage parties to be less transparent and collaborative.

Design management has a key role to play in all of these.

The lead designer may become the integrator. Design management will need to redefine their roles in that case. Their clients (and their commercial advisors) will need to restructure their cost models to recognise the effort this will involve, along with the subsequent cost benefits. This will change the cash flow profiles of projects as well as reducing overall costs. To improve productivity, we need to do things differently.

Supplier development should consider how designers can use their most competent resources to best effect and how quality assurance can be improved across their projects when there is less scope for person to person mentoring and supervision. Effective training methods need to be developed for the new way of working. The matrix management approach to projects will no doubt put more demands upon the professional line managers supplying expert staff to project managers. This study has highlighted the challenges of bringing new talent into companies, developing their competencies and knowing who to allocate to teams.

Designers are already facing a complex array of client needs. The number of different strategies covered in the RIBA Plan of Work 2020 highlights this. Measuring design performance is becoming increasingly challenging. However, most of a project's costs are determined in the design stages, with the largest decisions often made at the earliest strategy and conceptual stages.

Whilst it is difficult to quantify some of the qualitative factors that help deliver customer satisfaction, a lot of thought is going into the Government's Construction Playbook and the CIH's Value Toolkit, which should help achieve this.

By improving how we exploit manufacturing capabilities through design, develop strategies for eliminating non-value adding elements and other waste, great design can deliver superb facilities in ways that are easier for contractors to construct, more predictably, more quickly and more cost effectively. This is key to breaking through the construction sector's productivity barriers.

Academic research relating to a Systems Engineering based approach to construction design

The design of both buildings and infrastructure is becoming more complex, the performance of design is increasingly scrutinised with designers more accountable for the environmental performance and the health of users and to those that construct them. First rate design needs to accommodate the technical challenges of climate change mitigation, more complex integration of facilities (such as multi-modal transport) and the need to increase construction productivity.

In doing this, designs are increasingly likely to use offsite assembled elements in their solutions. In this context, it is not surprising that academics have been looking at the Systems Engineering-based processes mentioned above. Some of this research is summarised here. References to published papers are provided in the bibliography section. There is probably other related work happening elsewhere too.

At UCL, a combined team from the Centre for Systems Engineering and the Bartlett Faculty of the Built Environment have developed an approach based upon 5 principles. These are:

- Principles govern process
- Seek alternative systems perspectives
- Understand the enterprise context
- Integrate Systems Engineering and Project Management
- Invest in the early stages of projects.

Imperial College's Department of Civil and Environmental Engineering has been researching Systems Engineering and the project delivery process in the design and construction of built infrastructure, building on work that Prof. Jennifer Whyte started at Reading.

Reading has published a study of configuration management, involving Airbus, CERN, and CrossRail. It concluded: "...as managers in complex projects begin to deliver asset information, as well as assets, they should expect changes in both assets and associated asset information, and plan to manage this change. The second is that managers should be aware of the challenges that an 'era of big data' presents to this process of managing change. Configuration management provides a set of tools for maintaining integrity in this context, and implementation of configuration management has changed and is changing as a result of digital technologies". Reading's work also covers topics such as "Professionalism in digitally-mediated projects" and "Coordination and control in project-based work: digital objects and infrastructures for delivery".

The University of Manchester's School of Mechanical, Aeronautical and Civil Engineering has been working on configuration and product life cycle management for a long time, with Callum Kidd guiding their research. Nigel Fraser's project management master degree dissertation applied configuration to the construction design process of airport buildings. Other research that may help now includes papers on configuration management process capabilities, critical success factors for configuration management implementation and barriers to effective configuration management application in a project context. As more of construction becomes based upon "platforms" such as those being developed by the Construction Innovation Hub, Manchester's work on Product Lifecycle Management (PLM) will become more and more relevant. This will also help implement designing for whole life and resilience considerations.

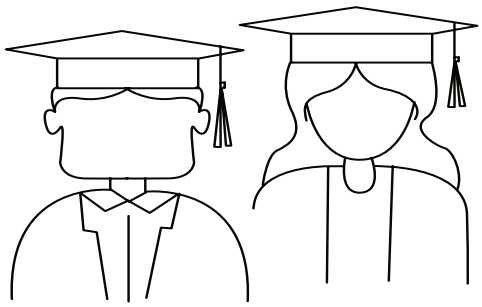
Nearby Salford University has also published work on "a requirements engineering framework for integrated systems development for the construction industry".

At Cambridge the Centre for Digital Built Britain (CDBB, part of the CIH) has published a "Pathway to the Development of the Information Management Network". At the time of writing this report there is an invitation to express interest in tendering for a project to develop a capability framework for skills to implement the Information Management Framework. Buildoffsite propose that some of the ideas and related skill requirements highlighted in this report should be considered in that context.

There are plenty of resources and insights available to us now to look at how such a Systems Engineering-based approach could be incorporated further into the way we manage the construction design process. It could be a key to developing processes that enable designers in a project team to work more independently of each other. Let's exploit this approach more.

Oxford Brookes, co-publisher of the Studio Guide to Modular Construction, is now developing the UK's first dedicated post-graduate architecture course covering modern methods of construction (MMC) and DfMA. Its Architectural Engineering Research Group is working with Buildoffsite and the architects Hawkins\Brown, Sheppard Robson, BPTW, PTEa, Stride Treglown and Levitt Bernstein to deliver this in the near future

At Edinburgh Napier, The Centre for Offsite Construction and Innovative Structures has launched the "Offsite Ready" programme. It provides training in related cost and procurement management and the function and role of design in projects using MMC.



4 Relevance to offsite construction

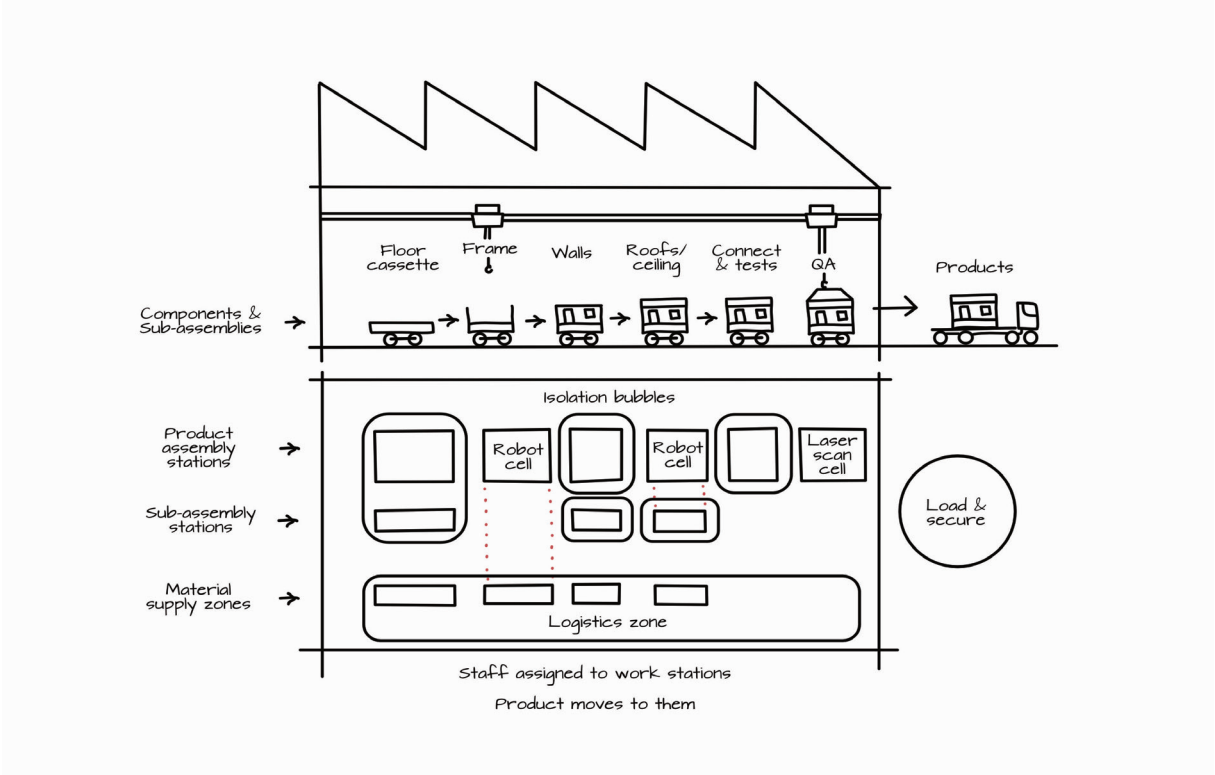
The COVID-19 pandemic has had multiple impacts upon the construction sector. It has however highlighted that it is easier to implement social distancing in factories than on construction sites. Not only is it a more controlled environment with greater scope for introducing one-way systems and maintaining sanitation posts, it also provides opportunities for work to move to the operative rather than the operative moving around a site. The factory-based workforce can often remain on their workstation on an assembly line.

Performance of factories has previously been demonstrated to be more predictable and this advantage has been magnified during the COVID-19 pandemic, where construction was able to continue at rates closer to normal than has been achieved on site. Factories can establish direct supply relationships with other manufacturers and are less likely to be reliant upon intermediaries such as builders' merchants/wholesalers. The setting up of the Nightingale Hospitals involved considerable use of offsite assemblies and other forms of MMC and demonstrated how offsite methods can accelerate projects.

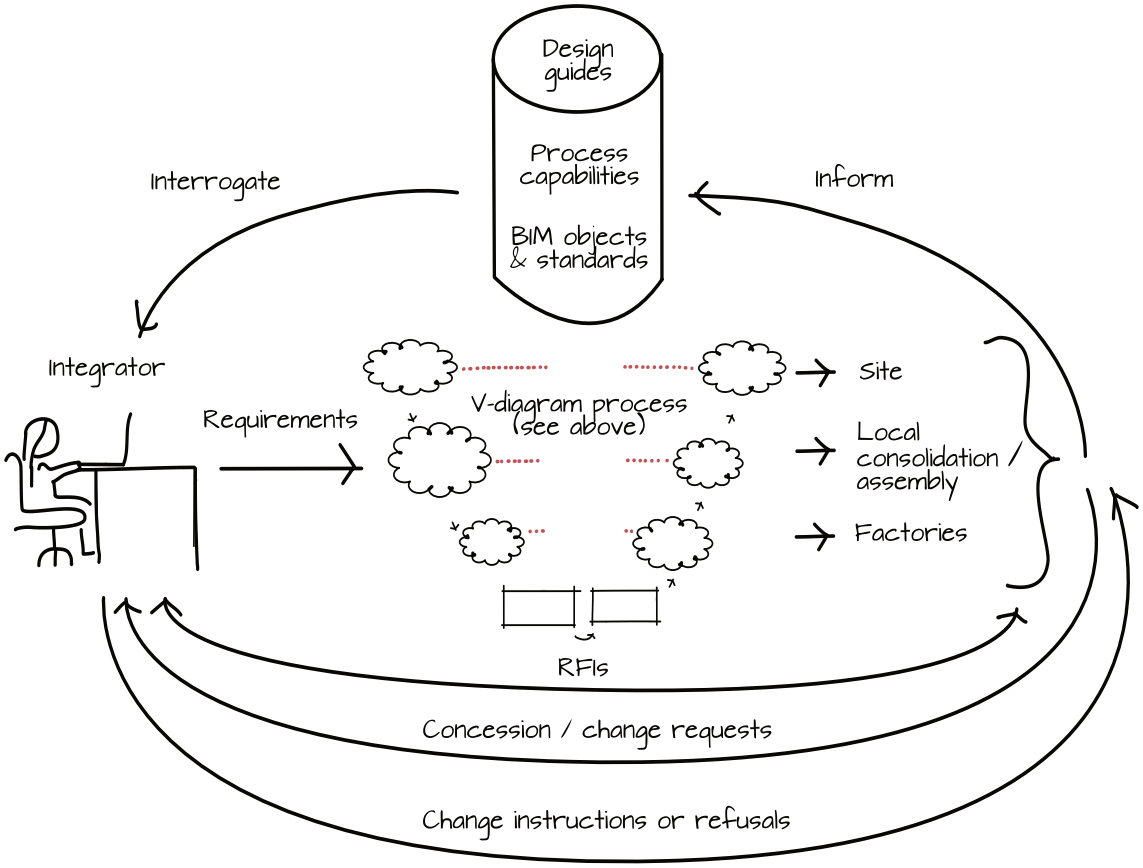
However, to get to this point, a supply contract needs to have been won by the factory. For that to happen, a facility needs to have been designed to an appropriate level of detail. A lot has been written about design for manufacture and assembly (DfMA). Using this process does not generally preclude something from being built traditionally, but one can expect the MMC advantage to open up over time as designers understand how to exploit new methods and more complex components become cheaper, for example as a result of continuous improvement programmes in factories, 3D printing, greater use of robotics and other innovations.

The approach to specifying the requirements of a new facility, a project, a work package or a task within one has been discussed above. By developing deeper understanding of MMC, including offsite, it is possible to unlock more potential from such methods. To do that the offsite industry needs to inform designers of their cost drivers (what to encourage or avoid) and interface requirements (e.g. to foundations etc.). Personnel drafting contracts (as well as designers) need to take this into account when specifying which standards (or specifications) to apply. Cutting and pasting old standards into contracts can lead to unintended contradictions, confusion and avoidable costs.

Remote working has increased the reliance on BIM models. One BIM manager at a large design company highlighted that after tender award even small changes can have a large cost impact and change management has to be established. Approximately 80% of their project work is now done using 3D geometry, which helped with remote working. Supplying designers with well-conceived 3D BIM objects for offsite assemblies is now a necessity.



A new way of working for the construction sector



Conclusions

Overall, the sector has demonstrated a remarkable ability to adapt to new and changing circumstances. Challenges have been met with enthusiasm to find solutions, even where those solutions may not yet have been found. People have been prioritising wellbeing, actively checking how their staff are coping and trying to be supportive. The sense of 'all being in this together' has been evident throughout the research culminating in this report, as people have generously given their honesty and time to provide an insight into their company and working lives during the pandemic, all with the aim of sharing information that might also help others in the sector.

This period has not been without its challenges as companies have had to adapt at pace without opportunities to trial new technology and find new ways of working. However, this has also helped accelerate change in positive ways. Many companies had plans to move to more cloud-based platforms, for example, but the pandemic meant this progressed rapidly. It is widely agreed that the 'office of the future' may look and feel quite different and that there will be a shift in how office buildings are used and more flexible working.

The importance of human interaction and social elements of the workplace was documented in this study. Social interactions are important to wellbeing and mental health, as well as training, building relationships in the workplace and in recruiting and inducting new staff. It is a change that we continue to adapt to as we try to replicate face to face interactions and develop a new etiquette for communicating virtually.

This research has also highlighted several potential solutions to challenges that can be adapted to the requirements of many contexts. It has also demonstrated how the construction design sector can learn from other industries and sectors to further improve productivity and processes, for example through configuration management, implementing a systems engineering approach to design, using QFD and removing barriers to innovations that could improve productivity.
We hope that sharing the information gathered will be useful to those involved in construction design management as we continue to reflect on how we do things and how we might improve productivity in the future.

The offsite sector clearly has a range of advantages to offer with respect to creating safe working environments, reliable, predictable delivery in adverse circumstances and opportunities for systematically reducing costs and improving quality through continuous improvement. For the wider construction sector to benefit from this, offsite suppliers need to ensure that designers are well informed and have easy access to appropriate BIM information.

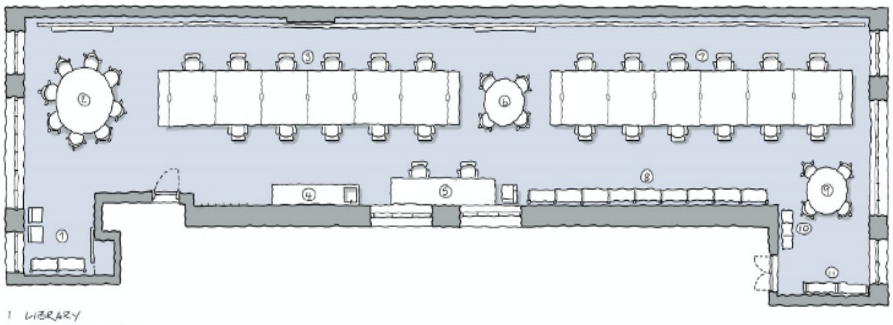
The role of the 'integrator' is likely to develop and emerge as a key change agent in the development of the construction sector. There is a wealth of academic work to help guide us forwards.

Let's make complex projects routine, of great quality, cost effective and predictable.

Appendices

Case studies

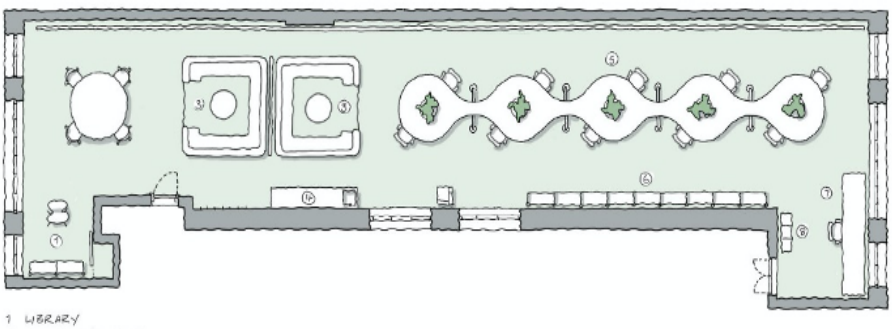
- **The pandemic office: David Miller Architects' response to the future of shared workspaces**



1 LIBRARY
2 BIG MEETING SPACE
3 TABLE 'A'
4 KITCHEN
5 HOT DESKS
6 SMALL MEETING SPACE
7 TABLE 'B'
8 TECHNICAL LIBRARY
9 SMALL MEETING SPACE
10 SERVER RACK
11 SAMPLE STORE

CURRENT MISSION ROOM

Architects are no strangers to turning conventional design on its head in order to improve function, usability and style. So, when a global pandemic emerged in early 2020 and the coronavirus saw many offices as we know them close, David Miller Architects seized the opportunity to reimagine their use of space – both in the office environment and the way it connects to the home.



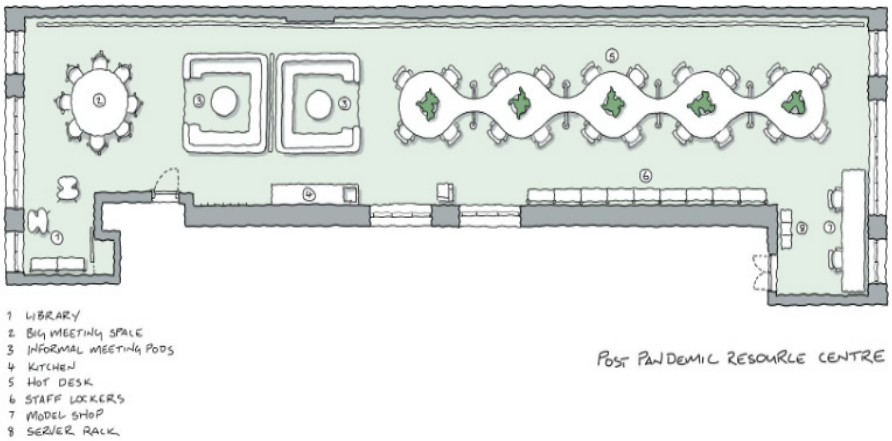
1 LIBRARY
2 BIG MEETING SPACE
3 INFORMAL MEETING PODS
4 KITCHEN
5 HOT DESK
6 STAFF LOCKERS
7 MODEL SHOP
8 SERVER RACK

TEMPORARY PANDEMIC LAYOUT

As the pandemic took hold, much of the UK workforce rapidly transitioned to flexible working, with many based at home and only commuting to a place of work when necessary. In response, David Miller Architects reconfigured their office space to include informal meeting pods, facilitating the exchange of ideas and the ongoing provision of support and mentoring for employees, overcoming a barrier of remote working, as well as providing socially distanced hot desks for those who were unable to work from home, and a clean and contained kitchen environment to prepare their own food.

Capacity for IT was reconfigured and connections carefully made to allow heavy duty computers in the office to shoulder the load of tasks like rendering, with their cues coming from lighter duty laptops, used at home.

By combining targeted infrastructure with innovative use of space, guided by the health and wellbeing of their employees, David Miller Architects were able to proceed with projects at a time when much of the economy was placed on pause. However, mentoring less experienced staff remained a challenge and idea exchange was tending to take up a significant amount of time on online meetings.



As lockdown restrictions begin to relax, but with the risks of the coronavirus still present, another spatial question is posed and David Miller Architects have sought to find solutions for this too.

Informal meeting pods and hot desks remain, reflecting a more flexible style of working with the need to social distance at the fore. The large meeting space returns to full capacity in anticipation of more people returning to work, but remains adaptable – not every seat must be filled. The office is still a key environment for facilitating mentorship and idea exchange. This enables safe opportunities to learn and collaborate and lead to a more effective understanding of each employee's capabilities, ultimately nurturing more productive project teams, whether working remotely, in the office, or on site.

The post-pandemic design feels grounded in the present and sensitive to the ongoing public health risk, while casting an eye to the future and the return of safe collaboration and new beginnings.

• Using videos to brief sites

In response to decreasing site access and ensuring minimal people were present at any one time, the Operations team at C-Probe recognised the need to find new ways of briefing installation contractors implementing their corrosion management systems designs on site.

These designs require specialist components to be retrofitted into existing structures, thereby integrating with details within the fabric of the structure. These require standard and bespoke detailing usually offered in CAD as well as by onsite presence from the company's operations engineers. The same scenario exists for precast or cast in-situ new build projects where components are installed before concrete is placed but require specific considerations.

With the Covid-19 pandemic making site activities difficult or non-existent (especially with projects in overseas markets), C-Probe looked at alternative ways to communicate with both client and contractor teams and keep production on site moving.

In lieu of briefing contractors, the team developed designs to remind contractors of what to do at each stage of implementation, replicating the guidance they would usually have given in person by creating a series of 'how to' videos. Building elements were mocked up in the workshop in St Helens and videos were filmed showing examples of how something would be done on site. Each component installation was separately demonstrated live using Microsoft Teams where the whole site team could observe the nuances of the installation as it happened and ask questions, where necessary, before translating these activities to the site. These videos were then exchanged with the contractors providing them with an archived resource to reference as they carried out their work.

This concept could be utilised in many ways to address the challenges thrown up by the pandemic, but also offered a cost-effective solution to site support that is emerging as a new normal for C-Probe's approach to servicing contracts, thereby lowering cost to the owner as well as keeping the company competitive. For example, videos could be created to replicate 'on the job' training for junior staff or training new recruits. Basic videos can be made very simply to serve this purpose with as little a smart phone camera and some imagination.

• Using QFD in construction design

Quality Function Deployment is perhaps an obscure term but takes a complex set of requirements and provides insights as to how they can best be met. It can be applied to an overall facility and cascaded to the elements that make it up. In simple terms, each stated need has to be measurable and a characteristic and unit of measure allocated to it. This may be the number of passengers that can pass through a station in a specific time-period, the number of platforms required, the amount of energy consumed per year etc.

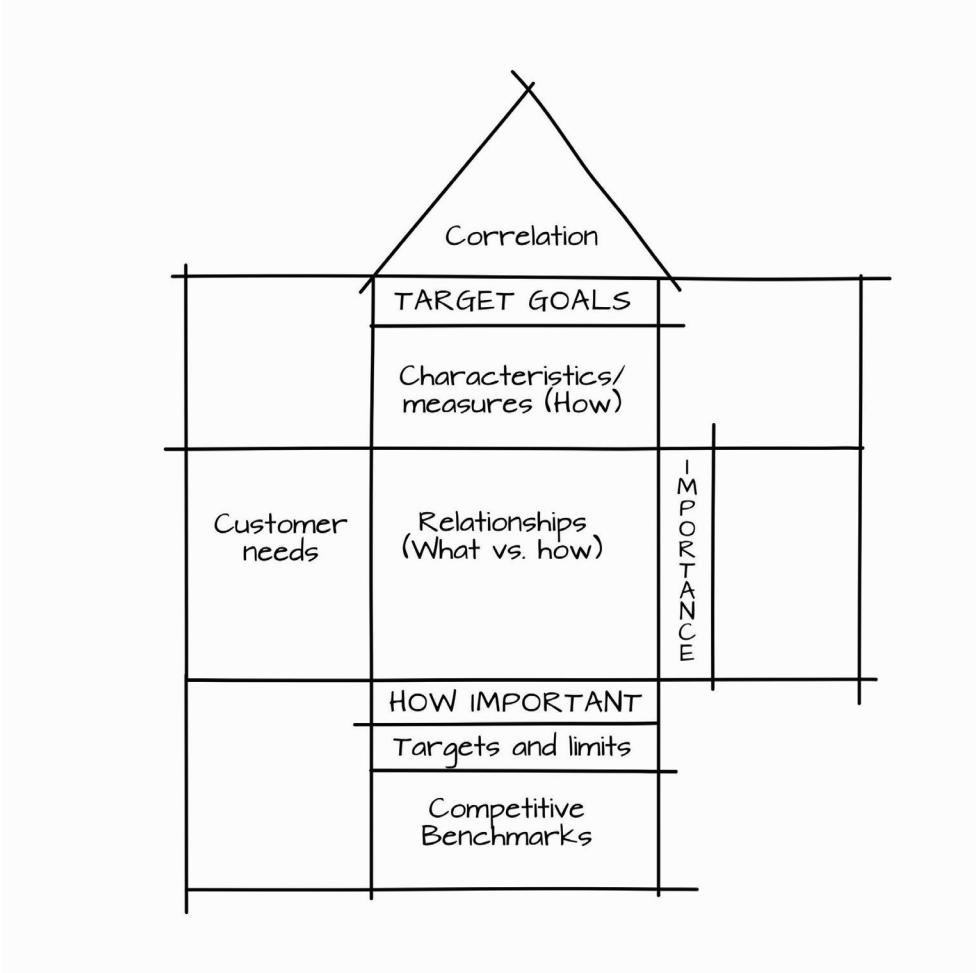
A matrix is then completed (a bit tediously) to indicate how strong the relationships are between all of the needs and all of the characteristics. Correlations are then identified between characteristics. These may be either neutral, positive or negative. Customer needs are rated in terms of importance (using typical market research tools such as conjoint trade-off analysis).

This leads to the ranking by importance of the different characteristics. These characteristics can be benchmarked against, for example, similar facilities. The client's targets, applicable standards and regulations are identified. From these, target goals are then set for the designers.

The information for the facility is presented in the format outlined below. Hence the term, "The House of Quality". This can then be repeated for the main elements that make up a facility (such as a building's structure or its façade) and ultimately to the choice of individual components.

The technique was initially developed in Japan by Professors Mizuno and Akao to design customer satisfaction into products. Mitsubishi Heavy Industries used a precursor of it at Kobe Shipyards for designing super tankers, which are kind of like big floating buildings, but it has since been used in many industries for designing both products and business processes. It has been used in the UK construction sector, for both a large strategy development project and a range of offsite assemblies.

Once the House (of Quality) has been built, it enables a team to make a series of decisions that are compatible with each other and that are traceable to specific client needs and priorities. It therefore has the potential to help teams who are working remotely to stay coordinated and consistent in their work and decision making.



- **The International Space Station (ISS)**

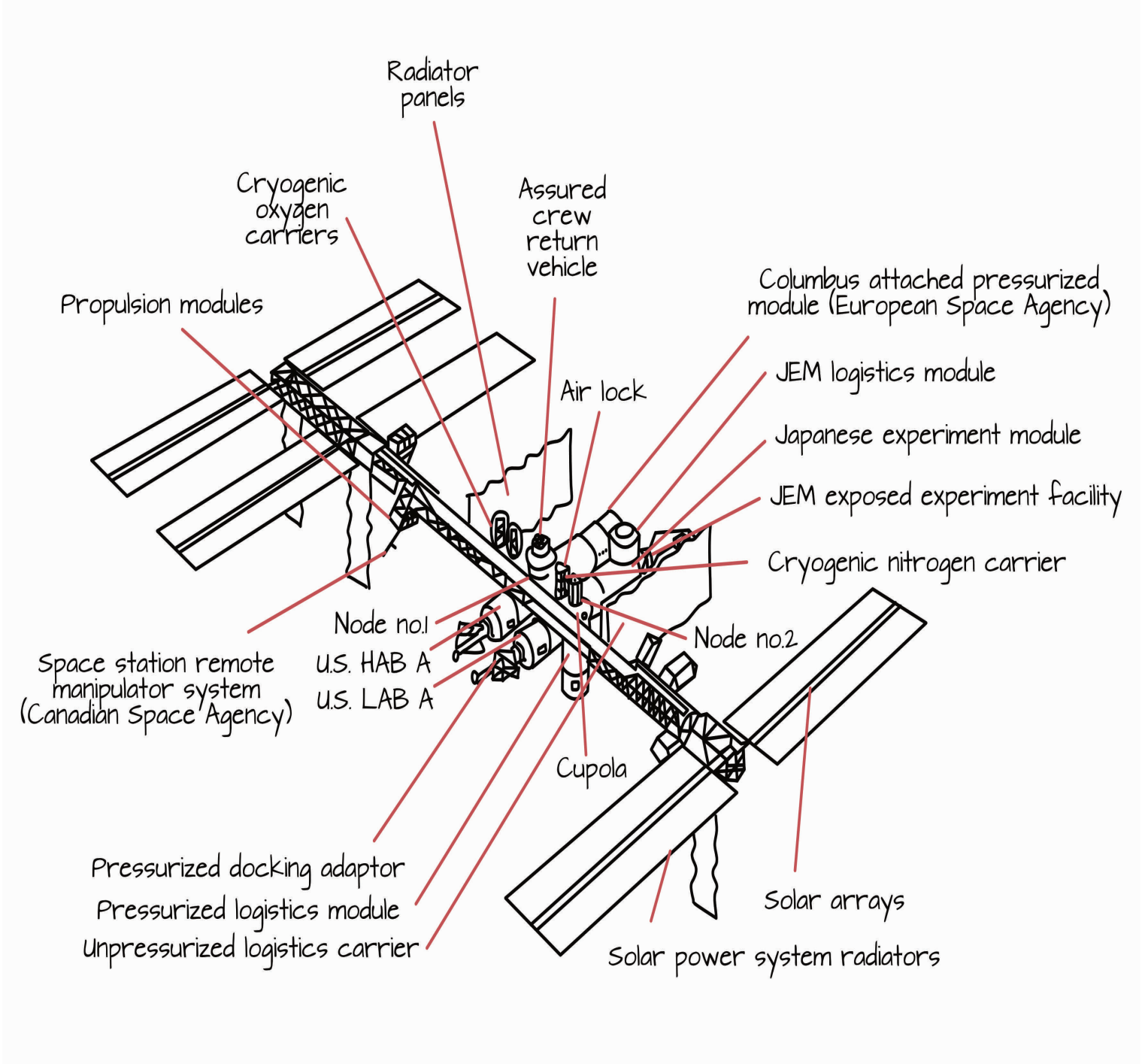


Figure: The modularity of the ISS (based upon the NASA image)

The ISS was the result of a hugely expensive offsite construction project. Between 1998 and 2011, 5 space agencies from 12 countries, supported by hundreds of manufacturers, built a home and laboratory in space using a configuration concept agreed upon in 1991. So, what has this to do with 21st century construction?

The answer is quite a lot. The concept was modular. The modules had to be manufactured offsite and assembled remotely. Modules had to fit and function first time. There was no scope for cost effective snagging! To achieve this, engineers used 2D and 3D CAD systems and rigorous configuration management. Many lessons were learnt and new techniques and ultimately process standards developed.

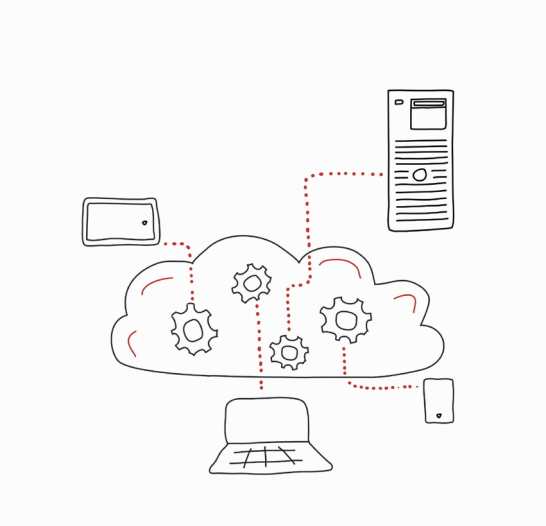
In the last 30 years computing capabilities and CAD systems have advanced considerably, not least with respect to BIM. Most designers now have access to far superior systems, both for designing physical elements and for collaborating across multi-disciplinary teams.

This example is presented to inspire us to look at other aspects that were used in developing the ISS, notably the systems engineering methodology supported by configuration management tools and their role in integrating the delivery of new facilities. We need to improve construction productivity. We need to eliminate non-value adding components in designs that are due to custom and practice, often embedded in published standards and technical guides that have become out of date. We need to make it easy to deliver facilities efficiently. And we need to do this for a fraction of the cost of an ISS module!

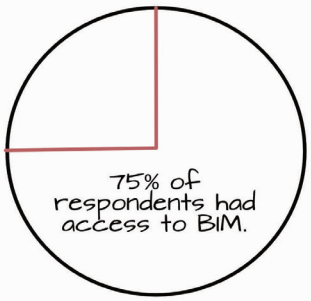
Survey Data

Study Contributors:	
Total	Role
9	Engineers
8	Architects & Senior Design Managers
6	Chairperson, Managing Directors & Directors
4	Project & Programme Managers
4	Customer Relations Managers
3	BIM Managers
3	Quantity Surveyors
3	Buyers / Senior Buyers
2	Offsite & Modular Buildings Managers
2	Non-specified consultants
1	Head of Post Completion
45	

AREAS OF CONSTRUCTION WORKED IN

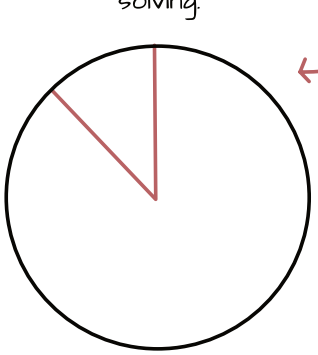


BIM

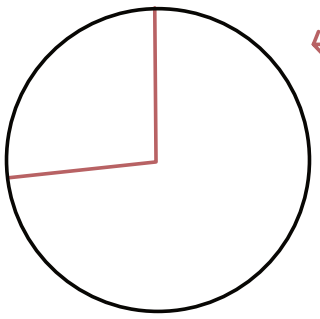


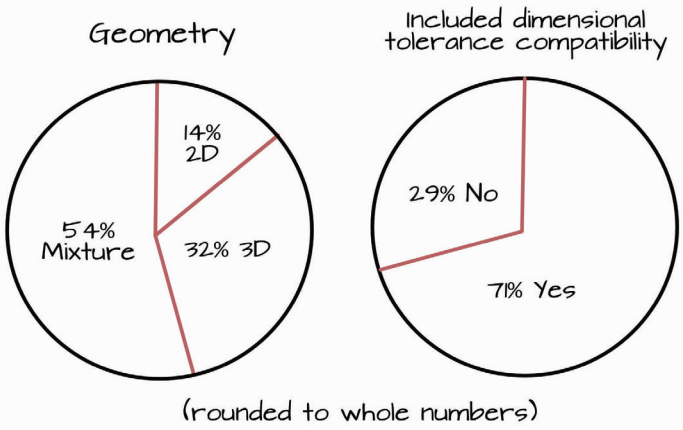
CREATIVITY

84% of people felt they had time for being creative and problem solving.



72% of people felt they had enough time for creative interactions with others.





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