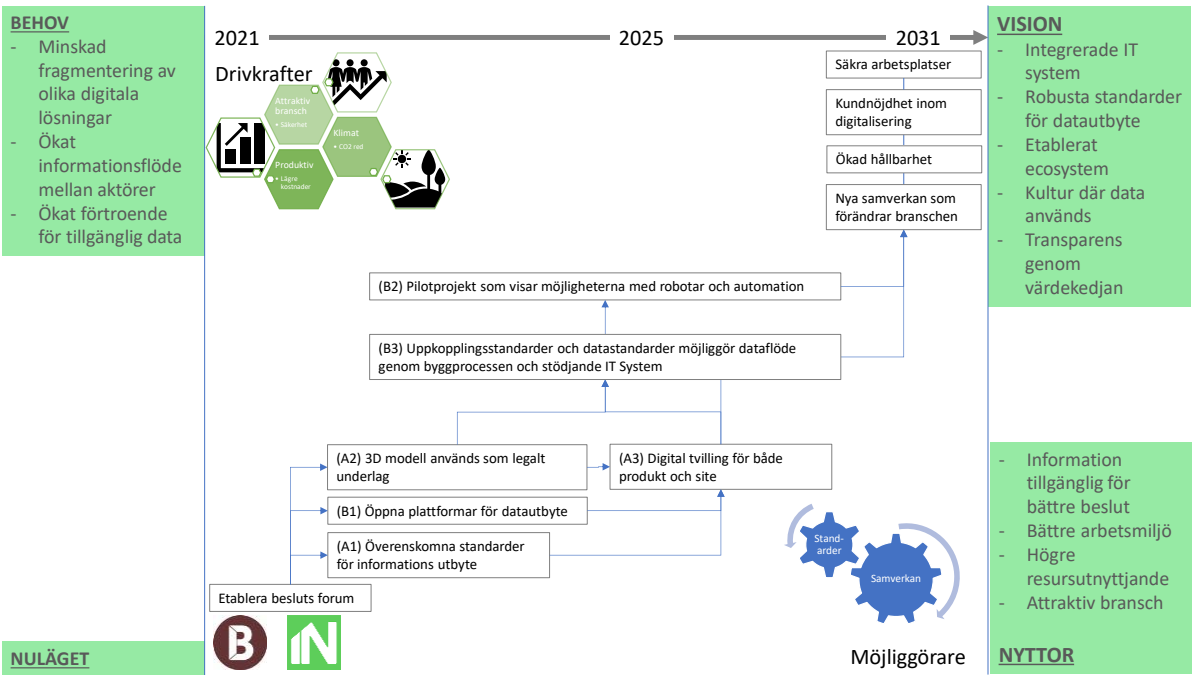
SBUF

SKANSKA

ID: 13959

NATIONELL FÄRDPLAN DIGITALA BYGGARBETSPLATSER

Beslutsunderlag till Byggföretagen och Installatörsföretagen



Joakim Jeppsson

2021-10-04

SBUF stödjer forskning & utveckling som leder till praktisk handling

FÖRORD

Undertecknad och arbetsgruppen framför härmed sitt tack till SBUF för deras finansiella stöd, och för det finansiella stöd som deltagande företag och organisationer stått för via sitt deltagande i workshopserien.

Totalt har 40 personer från 26 olika organisationer deltagit i den av Cambridge University ledda workshopserien. Entreprenörer, installationsföretag, universitet från Sverige och Finland, leverantörer av byggmaterial, byggsystem, utrustning till byggarbetsplatser, programvaruleverantörer, IT-konsulter och startup har bidragit till att skapa ett beslutsunderlag där olika perspektiv på den digitala byggarbetsplatsen finns representerade.

Intresset och engagemanget har varit oerhört stort, tack till alla involverade.

Speciellt tack till den arbetsgrupp som stöttat i planering och analysen av resultatet, bestående av:

Max Bergström, PEAB
Martin Rudberg, Linköpings universitet
Olle Samuelson, IQ Samhällsbyggnad
Kajsa Simu, NCC
Lars Stehn, Luleå Tekniska Universitet
Andreas Udd, VRA
Ronny Wahlström, Skanska
Karin Wikström, NCC

2021-10-05

Joakim Jeppsson

SAMMANFATTNING

Digitalisering är en fråga som berör hela samhället, den betraktas som en möjliggörare för många frågor såsom produktivitet, hållbarhet, säkerhet etc. Till följd av det stora intresset för frågan så pågår det sedan en tid tillbaka många initiativ kring digitalisering i form av strategiska innovationsprogram där digitaliseringen är en viktig del. Olika branschorganisationer, BIM Alliance, IQ Samhällsbyggnad (Smart Built Environment) och BEAst, driver och möjliggör olika digitaliseringsinitiativ med ansatsen att arbeta med digitaliseringen ur ett samhälls-byggnadsperspektiv. Det breda samhällsbyggnadsperspektivet behöver konkretiseras i sina respektive delar med ett fokus på värdeskapande på byggarbetsplatsen för nya konkreta insatser och för att dra full nytta av de pågående satsningarna på den övergripande nivån.

Storleken på programmen och antalet delprojekt gör att de resultat som kommer fram är svåra att transformera till praktiska färdigheter både för stora och små medlemmar i Byggföretagen och Installatörsföretagen. I syfte att häkta upp befintliga och kommande projekt och projektresultat i en struktur som möjliggör skalning i branschen så har i detta projekt ett förslag på en nationell färdplan för digitala byggarbetsplatser utvecklats.

Det föreslås att Byggföretagen och Installatörsföretagen enas om en gemensam vision. Robusta standarder för datautbyte skall ge stora och små företag möjligheten att integrera sina IT system med byggarbetsplatserna. Då kan det etableras ett innovativt digitalt ekosystem för branschen, vilket möjliggör ökad transparens och en kultur där data används i högre omfattning. Den tillgängliga informationen förväntas leda till bättre arbetsmiljö, högre resursutnyttjande och en attraktivare byggbransch.

I dagsläget är behovet i branschen och för dess leverantörskedja minskad fragmentering av digitala lösningar, ökat informationsflöde mellan aktörerna och ökat förtroende för tillgängliga data.

Första steget i den föreslagna färdplanen är att etablera ett samverkansform för Byggföretagens och Installatörsföretagens samtliga medlemmar där frågorna kan diskuteras och prioriteringar göras för att minska den digitala fragmenteringen.

Därefter har i rubrikform sex utvecklingsområden identifieras, för varje område behöver en nulägesanalys och projektplan etableras. Utvecklingsområdena är;

- Överenskomna standarder för informationsutbyte
- Öppna plattformar för datautbyte
- 3D-modell används som legalt dokument
- Digital tvilling för både produkt och byggarbetsplats
- Uppkopplingsstandarder och datastandarder som möjliggör dataflöde genom byggprocessen och stödjande IT-system
- Pilotprojekt som visar möjligheterna med robotar och automation

Rapporten har presenterats för VD i Byggföretagen och Installatörsföretagen, samt för Byggföretagens förbundsstyrelse. Arbetsgruppen föreslår att ett nytt SBUF-projekt söks för att arbeta fram ett underlag för en av ovanstående punkter för att skapa en gemensam bild av struktur och arbetssätt för samverkansgruppen, detta sker parallellt etablering av, och tillsättning av representanter i samverkansforumets.

Innehåll

1 Bakgrund

Det är på byggarbetsplatserna som bygg- och installationsbolagen (hädanefter benämnda bolagen) har sin inkomst. Digitaliseringen i samhället och den digitala utvecklingen möjliggör nya arbetssätt och användningen av nya teknologier för ökad produktivitet, bättre arbetsmiljö och minskad miljöpåverkan på våra arbetsplatser, men vägen dit är oklar.

Bolagen i Sverige är för små för att driva en branschöverskridande digital förändringsstrategi och färdplan för digitaliseringen av sina egna arbetsplatser. Branschstrukturen med gemensamma beställare som ställer samma krav på alla sina leverantörer, gemensamma underleverantörer, materialleverantörer och underentreprenörer gör också att behovet av gemensamma digitala strukturer blir relevanta att utreda.

För att uppnå en gemensam plattform behövs en gemensam strategi och därtill hörande färdplan. Detta projekt syftar till att beskriva en möjlig gemensam färdplan för den långsiktiga digitala utvecklingen på våra arbetsplatser, samt behovet av insatser för att kunna uppnå målen i färdplanen.

Färdplaner av det här slaget har ett stort kommunikativt värde då det ger branschen och våra leverantörer möjligheten att samordna och takta sin utveckling för en effektiv och snabb omställning till säkrare, hållbarare och produktivare arbetsplatser. Färdplanen har också ett stort värde i fortsatt dialog med forskningsfinansiärer och andra statliga intressenter som gärna ser kopplingen till industribehov i de forskningsprogram de finansierar.

I dagsläget pågår många initiativ, delvis osynkroniserade och inte alla med förståelse för byggarbetsplatsen behov och effektmål inom: produktivitet, hållbarhet och säkerhet. Detta projekt tar sin utgångspunkt i det nätverk som finns inom ramarna för ”Uppkopplad byggplats”[1], som är ett strategiskt projekt inom Smart Built Environment[2], ett av landets 17 strategiska innovationsprogram[3].

2 Syfte

Syftet med projektet är att ta fram ett beslutsunderlag för en färdplan för entreprenörernas digitaliserade arbetsplatser. Väl fungerade arbetsplatser med högre grad av digitalisering än idag är en möjliggörare många av branschens prioriterade områden;

- Produktivitet
- Klimatomställning
- Säkerhet
- Spårbarhet och transparens

I utvecklingen av färdplanen beskrivs ett syfte som skiljer sig från projektets. (Phaal, Roadmapping for strategy and innovation, 2015) beskriver i generella termer syftet med färdplanearbete som något som används för att synkronisera utveckling och andra investeringar med mål och strategier. Syftet för färdplanen i sig definierades enlig nedan för workshopdeltagarna.

- Fånga lärdomarna från genomförda pilotprojekt så att de kan inkluderas i nästa utvecklingssteg

[1] https://uppkoppladbygg.se/om-uppkopplad-byggplats/vad-uppkopplad-byggplats/
[2] https://smartbuilt.se/om-oss/
[3] https://www.vinnova.se/m/strategiska-innovationsprogram/

- Förstå trender och perspektiv från värdekedjan som är viktiga för utvecklingen av digitala lösningar
- Beakta olika visioner tvärs branschen från bolagen, akademin och leverantörer
- Definiera vilka produkter och tjänster som behövs, samt de hinder som finns för deras användning
- Identifiera de innovationer och den teknik som möjliggör framtida framgång
- Utvärdera i detalj de viktigaste stegen för framtida framgång

Nyttan med en beslutad långsiktig färdplan som aktivt följs upp och justeras kan inte underskattas ur ett kommunikativt perspektiv. En branschgemensam riktning skapar trygghet för många leverantörer, de vet vad som gäller över tid, de kan planera sitt eget utvecklingsarbete i förhållande till den tidsplan och de regler som sätts upp av branschen.

På samma sätt är ett gemensamt åtagande något som vid behov kan användas i dialog med relevanta forskningsfinansiärer.

3 GENOMFÖRANDE

3.1 Allmänt

Projektet genomfördes som en workshopserie där deltagare från bolagen, akademi, leverantörer och tech bolag var aktiva. Dessa deltagare redovisas i Bilaga – Connected Construction sites – Strategic Roadmapping.

Tabell 3-1 redovisar projektorganisationen och den arbetsgrupp som tillsammans med projektledare planerade och följde upp workshop serien. Arbetsgruppen har också arbetat fram det förslag på fortsättning som redovisas i avsnitt 5.

Cambridge Engage var drivande i processen så till vida att de arbetade fram material och bearbetade resultaten från workshoparna. Arbetsgruppen var styrande och satte ramar och gjorde avgränsningar för att säkerställa att de frågor vi önskade svar på skulle bearbetas i workshoparna. Detaljerad beskrivning av arbetssättet finns i Bilaga – Connected Construction sites – Strategic Roadmapping.

Bilaga – Connected Construction sites – Strategic Roadmapping redovisades för projektsponsorerna 2021-06-23. Resultatet presenterades också som en informationspunkt på förbundsstyrelsen för Byggföretagen 2021-09-01.

Tabell 3-1 Projektorganisation.

Projektsponsorer	**Projektledare**
Catharina Elmsäter-Svärd, Byggföretagen, VD Ola Månsson, Installatörsföretagen, VD	Joakim Jeppsson, Skanska Sverige AB
Arbetsgrupp;	**Workshop facilitatorer;**
Max Bergström, PEAB Martin Rudberg, Linköpings universitet Olle Samuelsson, IQ Samhällsbyggnad Kajsa Simu, NCC (lämnade över till Karin Wikström) Lars Stehn, Luleå Tekniska Universitet Andreas Udd, VRA Ronny Wahlström, Skanska Karin Wikström, NCC	Colin Haden, Cambridge Engage (lead) Arslan Ghani, Cambridge Engage Andi Jones, Cambridge Engage Nic Sullivan, Cambridge Engage Nicky Athanassopoulou, Cambridge Engage

3.2 Teoretiskt ramverk

Färdplanen utarbetas med hjälp av ett ramverk för strategi och innovation som är utvecklat vid Cambridge University (Phaal, Roadmapping for strategy and innovation, 2015). Normalt genomförs merparten av det här arbetet i en endags snabbstarts workshop men på grund av rådande omständigheter genomfördes arbete i en online baserad workshop serie.

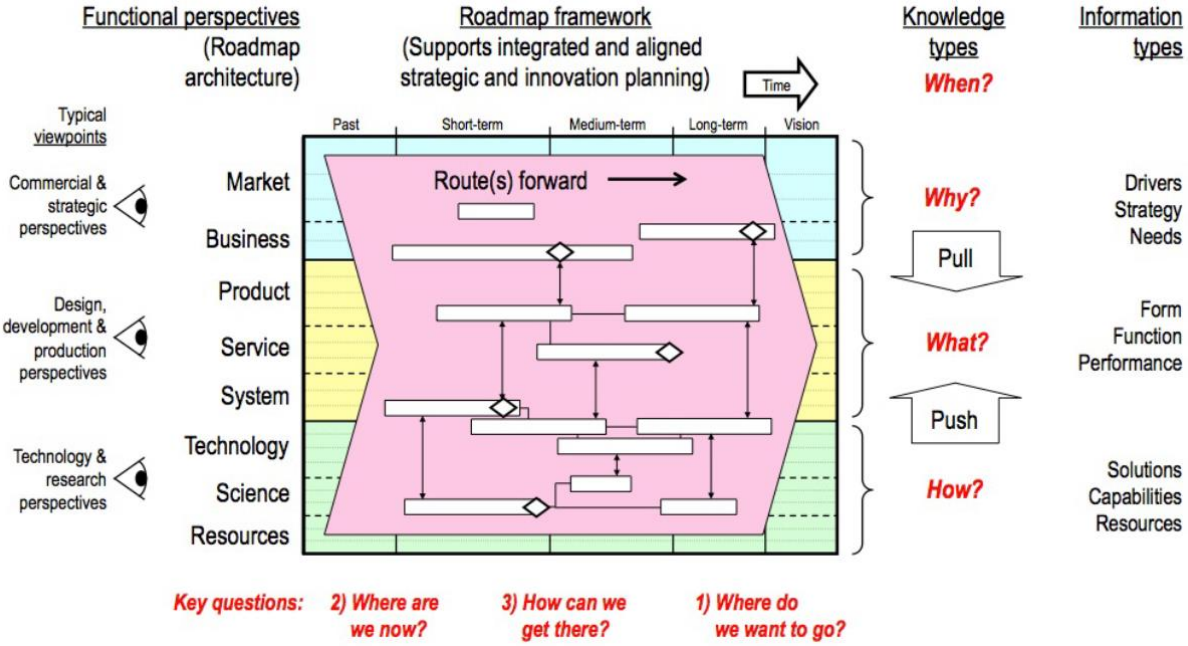
Ramverket används för att identifiera tekniska möjligheter kopplade till affärsbehov, vilket är kärnfrågan kring hur digitaliseringen används för att öka produktiviteten, säkerheten och underlätta hållbarhetsarbetet på våra arbetsplatser. Metoden har framgångsrikt använts för att finna ny teknik åt olja och gas sektorn[4], järnvägssäkerhet ur ett branschperspektiv[5], och för att skapa en långsiktig färdplan för Centre for Digital Built Britain[6].

Grunden för ramverket är de tre nyckelfrågorna;

1.) Var vill vi vara?
2.) Var är vi nu?
3.) Hur tar vi oss dit?

I workshopgenomförandet läggs fokus på att definiera de tre nyckelfrågorna genom att tydliggöra frågorna;

a.) Varför behöver vi göra något?
b.) Vad skall vi göra?
c.) Hur gör vi det?



Figur 3-1 Dynamiskt ramverk för strategi och innovation (Phaal, Roadmapping for strategy and innovation, 2015).

[4] https://www.ifm.eng.cam.ac.uk/uploads/Roadmapping/Oil_and_Gas_Multinational.pdf
[5] https://www.ifm.eng.cam.ac.uk/ifmecs/business-tools/roadmapping/roadmapping-case-studies/rssb-case-study/
[6] https://www.cdbb.cam.ac.uk/

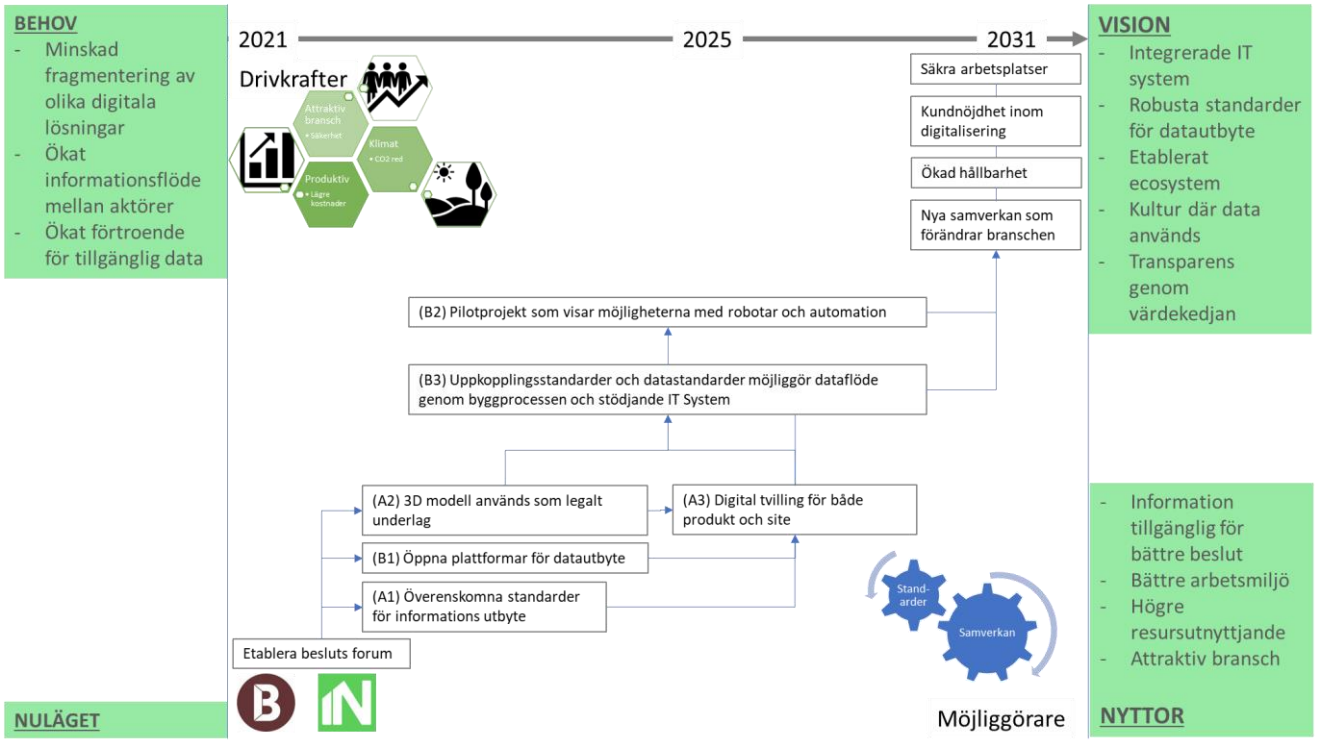
3.3 Reflektion

Några av arbetsgruppens reflektioner återges här;

- Engelska som arbetsspråk upplevdes av vissa som hämmande
- Vi hade med oss 40 kloka personer som på ett strukturerat sätt kunde delge oss sina tankar
- Strukturen låg även till grund för bolagsinterna diskussioner i nya interna konstellationer som inte gjorts annars
- Arbetsgruppen har samverkat bra under hela projektet
- Projektets ansats är långsiktighet, de som hoppade med för att hitta snabba affärer försvann under resans gång
- Förankring av utvecklingsresultat är viktigt, det som får fäste i branschen är handfasta konkreta resultat, tänk BEAst Granskning
- Alla kände inte igen sig i den bild som växte fram, men efter att reflekterat över resultatet känns det rimligt för samtliga i arbetsgruppen
- Data från arbetet kan ges olika tolkningar, och det kan finnas perspektiv som inte fångats av arbetsgruppen
- Då det pågår mycket inom flera av de identifierade områdena, varför en mappning mot dessa är central inför fortsättningen

4 RESULTAT

Baserat på det strategiska landskapet (Figur 4-2) samt de ämnesroadmappar (A1-A3, B1-B3) i Figur 4-1 så har nedanstående förslag på färdplan etablerats. Detaljer för både det strategiska landskapet och ämnesroadmapparna finns i bilagan. I Figur 4-1 framgår att ett 10 års perspektiv på arbetet anlades.



Figur 4-1 Föreslagen färdplan.

Det föreslås att Byggföretagen och Installatörsföretagen enas om en gemensam vision. Robusta standarder för datautbyte skall ge stora och små företag möjligheten att utbyta data mellan sina

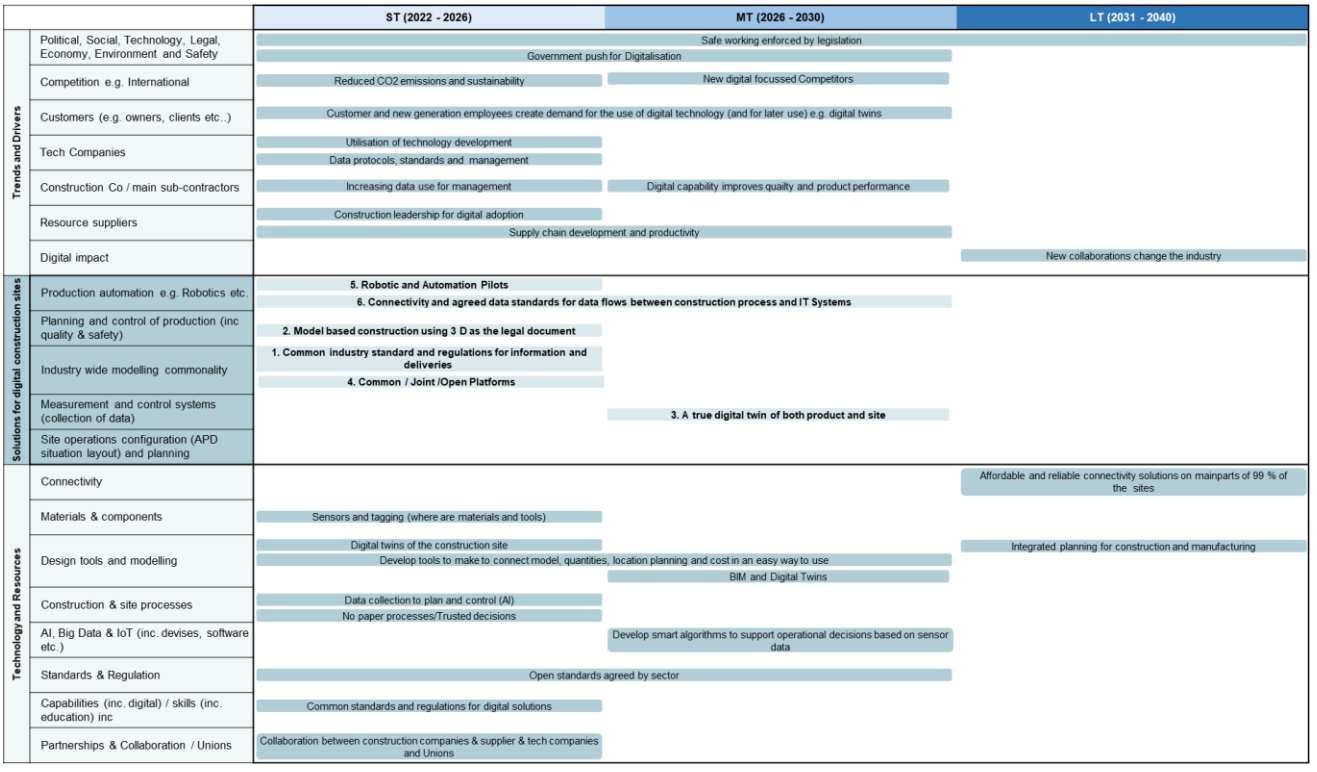
IT-system och byggarbetsplatserna. Då kan det etableras ett innovativt digitalt ekosystem för branschen, vilket möjliggör ökad transparens och en kultur där data används i högre omfattning. Den tillgängliga informationen förväntas leda till bättre arbetsmiljö, högre resursutnyttjande och en attraktivare byggbransch.

I dagsläget är behovet i branschen och för dess leverantörskedja minskad fragmentering av digitala lösningar, ökat informationsflöde mellan aktörerna och ökat förtroende för tillgängliga data.

Första steget i den föreslagna färdplanen är att etablera ett samverkans forum för Byggföretagens och Installatörsföretagens samtliga medlemmar där frågorna kan diskuteras och prioriteringar göras för att minska den digitala fragmenteringen.

Därefter har i rubrikform sex utvecklingsområden identifieras, för varje område behöver en nulägesanalys och projektplan etableras. Utvecklingsområdena är;

- Överenskomnas standarder för informationsutbyte
- Öppna plattformar för datautbyte
- 3D modell används som legalt dokument
- Digital tvilling för både produkt och site
- Uppkopplingsstandarder och datastandarder som möjliggör dataflöde genom byggprocessen och stödjande IT system
- Pilotprojekt som visar möjligheterna med robotar och automation



Figur 4-2 Strategiskt landskap

5 SUMMERING

5.1 Överlämning

Avrapportering till Byggföretagen och Installatörsföretagen gjordes 2021-06-23, därpå följde en presentation för Byggföretagens förbundsstyrelse 2021-09-01 med en uppmaning att beskriva hur arbetat tas vidare i det samverkans forum som föreslås.

5.2 Diskussion

Arbetsgruppen träffades 2021-09-13 och nedanstående är en summering av denna diskussion. Diskussionspunkterna som redovisas nedan understryker det faktum att framtaget förslag på färdplan är en snabbt framtagen startpunkt och att fortsatt arbete behövs för att driva och följa och justera under en längre tid framöver.

Arbetsuppgifter för samverkansforumet

- Hur görs den praktiska prioriteringen av vad som skall utredas gemensamt?
- Hur sker samordning mellan detta forum och andra pågående program, aktiviteter och existerande branschorganisationer?
- Strukturering av sektorsgemensam input till ovanstående
- Kommunikation till medlemmar i Byggföretagen och Installatörsföretagen
- Färdplanen används som startskott för Byggföretagen att driva digitaliseringsfrågan på samma sätt som säkerhetsfrågan
- Implementering är svårt, en första uppgift kan vara att analysera goda och dåliga exempel på implementering för att hitta bra sätt
- Är certifiering ett sätt att driva på implementering och förändring
- Akademins och techbolagens roll i samverkansforumet behöver utredas
- Färdplanen kan ge akademin input till utbildningsinnehåll för studenterna och det livslånga lärandet

5.3 Fortsättning

Baserat på den i korthet redovisade diskussionen i avsnitt 5.2 föreslås följande åtgärder.

Etableringen av samverkansforum (med lämpligt namn) kan kommuniceras av Byggföretagen och Installatörsföretagen.

Ett nytt SBUF projekt söks där fortsatt engagemang från nuvarande arbetsgrupp används för att arbeta fram ett förslag på hur arbetet organiseras framöver, detta möjliggör utformning av en lämplig kravprofil på den projektledare som troligen behövs.

Det nya SBUF projekt inleds med att en prioritering görs kring vilken eller vilka av de sex identifierade områdena som skall utredas. Därpå tas ett beslutsunderlag fram åt deltagarna i samverkansforum, arbetet ger direkta erfarenheter som kan användas för att etablera arbetssätten kring;

- Prioritering
- Nulägesanalys
- Behovsanalys
- Samordning mot pågående program och aktörer
- Hur kommunicera med medlemsföretagen
- Kompetensbehov i arbetet, hur involvera akademi och techbolag

5.4 Kommunikation

I samband med etableringen och kommunikation kring detta så bör en intressentanalys genomföras så att riktad kommunikation kring färdplanens innehåll kan ges till relevanta intressenter, såsom branschföreningar, forskningsfinansiärer, Sveriges Bygguniversitet etc.

Litteraturförteckning

Phaal, R. (2015). Roadmapping for strategy and innovation.

Phaal, R. (u.d.). *Cambridge Roadmapping*. Hämtat från https://www.cambridgeroadmapping.net/ den 06 08 2021

Bilaga – Connected Construction sites – Strategic Roadmapping

Infogat på efterföljande sidor finns den skriftliga dokumentation av workshoparna som Cambridge University tillhandahållit.

Connected Construction Sites Strategic Roadmapping

Report commissioned by Development Fund of the Swedish Construction Industry (SBUF)

1st June 2021

UNIVERSITY OF CAMBRIDGE
Department of Engineering

IfM Engage

1. Executive Summary

Following a €4M invested in three key projects for ‘Connected Work Sites’ over the last five years, the SBUF sponsored this project with the aim to develop a strategic roadmap that would define the next steps to enable digitally connected construction sites. The project focussed upon the construction site and the related activities of product; planning; supply processes; including safety; environment; efficiency; integrated planning (incl. linkages to the design phase); and model-based construction.

The project started with developing the key lessons from the past projects followed by developing a Vision created from the perspectives of academia, construction, suppliers and technology companies. This allowed the use of the University of Cambridge Strategic Roadmapping using a fast start S-Plan. This approach is used because it is an agile strategic planning technique for the development and communication of strategy and innovation across industry, and academic organisations to bring clarity to complex problems and alignment of purpose. A total of 5 facilitators from IfM Engage were involved to conduct workshops. The project engaged 41 participants from 28 companies into 4 groups. A total of 4 facilitated workshops were conducted related to Lesson Learnt; Vision/Trend, Drivers and Challenges; Solutions/Technology and Resources; and Topic Roadmaps. The project guidance was given by 9 Industry representatives. Throughout the process all the inputs from delegates have been captured and consolidated for use after the project
.
The result of the Roadmap, was the decision by the Design Team to explore the most promising outcomes through Topic Roadmapping of:

- Developing common data standards/regulations
- Model-based construction using 3 D as the legal document
- Use of digital twins demonstrators
- Common / Joint /Open Platforms
- Robotic and Automation Pilots
- Connectivity and agreed data standards for data flows between construction process and IT Systems

This project document provides a strategic roadmap with actionable start and recommendation to the SBUF, Installatörsföretagen and the leading construction business to develop digitally connected work sites in Sweden.

In summary the delegates want to enable the development of a competitive and productive industry delivering the best possible safety with minimal impact on the environment. This will need leadership, the support of parastatals and leading construction companies.

Contents

2. Workshop Context

2.1 Background

The Swedish Government, through Energimyndigheten (the Swedish Energy Agency), Vinnova and Formas (the research council for sustainable development) finances strategic innovation programmes supported by academia and industry. Smart Build Environment was one of 17 strategic programmes aimed at exploring new opportunities in digitalisation focussed on the Swedish construction sector, and €4M was invested in 'Connected Work Sites' (Uppkopplad byggplats). Over the last five years, major construction businesses, sub-contractors, suppliers, and two universities were engaged, and multiple pilots have been studied to investigate the relevance and use of digital technology in the Swedish construction sector.

There was significant learning for stakeholders from the 'Connected Work Sites' project motivating further developments by Swedish construction Industry. Therefore a grant was applied for through SBUF (the construction industry's organisation for research and development) for the development of a roadmap). The Swedish Construction Federation (Byggföretagen), representing 3,700 construction companies and employers in Sweden, together with the Swedish Installation Federation (Installatörsföretagen) representing 3,600 installation companies and employers in Sweden took on the role of project sponsor and recipients of the roadmap delivered by IfM Engage. Through the roadmapping approach, it was requested that the project should involve representatives from, academia, technology companies, resource suppliers alongside the construction business to define the next phase of digital developments. With Byggföretagen and Installatörsföretagen as the main sponsor for this roadmapping project, Joakim Jeppsson (Skanska Sweden) managed the project.

2.2 Objectives

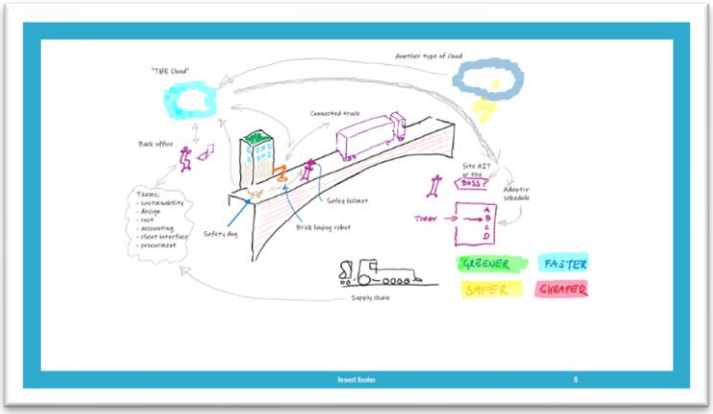
Specifically, for the time frame 2022 - 2040 to:

- Capture the key learnings from the pilots so that they can be incorporated into the next phase of developments
- Understand the trends and value chain perspectives that will be the key drivers for digital technology
- Consider perspectives on the vision for digital developments across industry, academia, and suppliers
- Define what digital product/services are needed including the barriers to introduction (and their solutions)
- Establish the innovation, technology, and other enablers necessary for success.
- Explore priority projects in detail to identify key steps and milestones to their successful delivery.
- These objectives should be considered in the context of short, medium, and long-term periods.

2.3 The Project Scope

Table 1 - Scope

Scope defined by the Design team	
Included	Digitalisation of construction with a focus on the construction site's production planning and supply processes including safety, environment, efficiency, integrated planning (incl. linkages to the Design phase) and model-based construction. This includes: • The full production phases • Linkages between the Design phase and production (Design to support function of production)
Excluded	Activities outside the construction process e.g.: • Building maintenance • Long term maintenance and operation. • Early phase planning and Designing



To further assist delegates the scope was conceptualised to aid discussions (Fig 1.)

Figure 1 - Sketch to illustrate the scope

Prior to the first workshop, the prework requested of delegates was analysed and presented to the Design Team. The results showed that input focussed on the technology and equipment, and it would also benefit from considering other aspects such as people and change management. As a result, ahead of the visioning session, some refinements were made to the scope to switch the emphasis from technology to what is needed and how could technology support this?

Table 2 - Revision to project vision

Prework analysis		Revisions for Visioning
Lessons learned put a focus on: • Ad hoc testing of available technologies • Technology driven approach	➔	Additional dimensions: • Organisation • Processes • Personas new digital work life • Company aspects as opposed to project aspects

The changes to enhance the scope was communicated to the delegates at the start of every workshop with a revised concept diagram:

> "A focus on the construction site's production planning and supply processes including safety, environment, efficiency, integrated planning (incl. linkages to the Design phase) and model-based construction enabled by digitalisation."

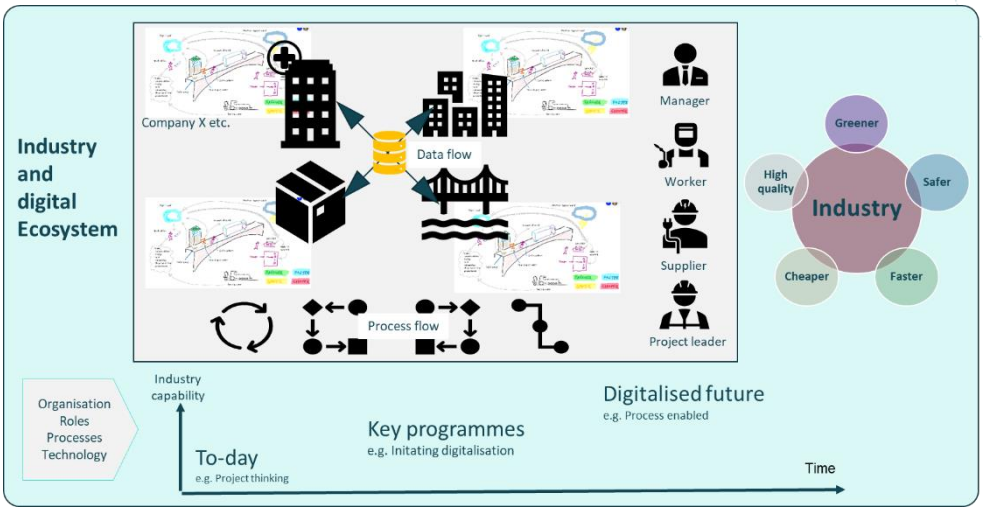
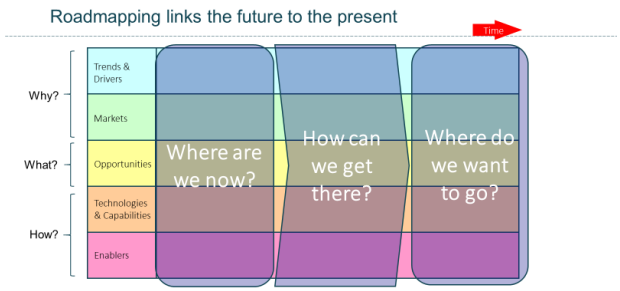


Figure 2 - Revised concept

2.4 Approach and Methodology

The methodology for this project was a 'Fast Start' Strategic Roadmapping process (S-Plan) used retrospectively for Lessons Learned and looking forward for the other workshops. Fast start is used as the optimum way to achieve a strategic perspective balanced with the time available from delegates. More information on Roadmapping is given in appendix J. In this report there are references to 1) the Why layer or trends and drivers (e.g. why change), 2) the What layer or solutions/opportunities (What is needed?) and 3) the How later or technology / resources/ enablers (e.g. how can it be done).



The Institute for Manufacturing (IfM) is a division of the Department of Engineering at the University of Cambridge. As an international leader in the research and application of Roadmapping, it has developed the methodology that has been used in this project. The IfM knowledge transfer and applications team, IfM Engage, worked with the Design team and project manager to deploy the Roadmapping framework.

Figure 3 - https://engage.ifm.eng.cam.ac.uk/roadmapping/

The project was delivered through a series of on-line collaborative workshops. Ahead of each workshop, the best knowledge available was gathered and consolidated from the construction and related industries, covering academia, technology companies, resource suppliers and the construction Industry. The workshops were dedicated to the discussion and review of information to understand and share insight.

Note: The workshops were held during the Covid-19 pandemic and as a result all sessions were held remotely, with session durations no longer than 2.5 hours, using a combination of Excel template, Zoom conferencing and Miro digital whiteboards. Because time is limited prework was used to build content and the workshops used for review, discussion, additions, and voting.

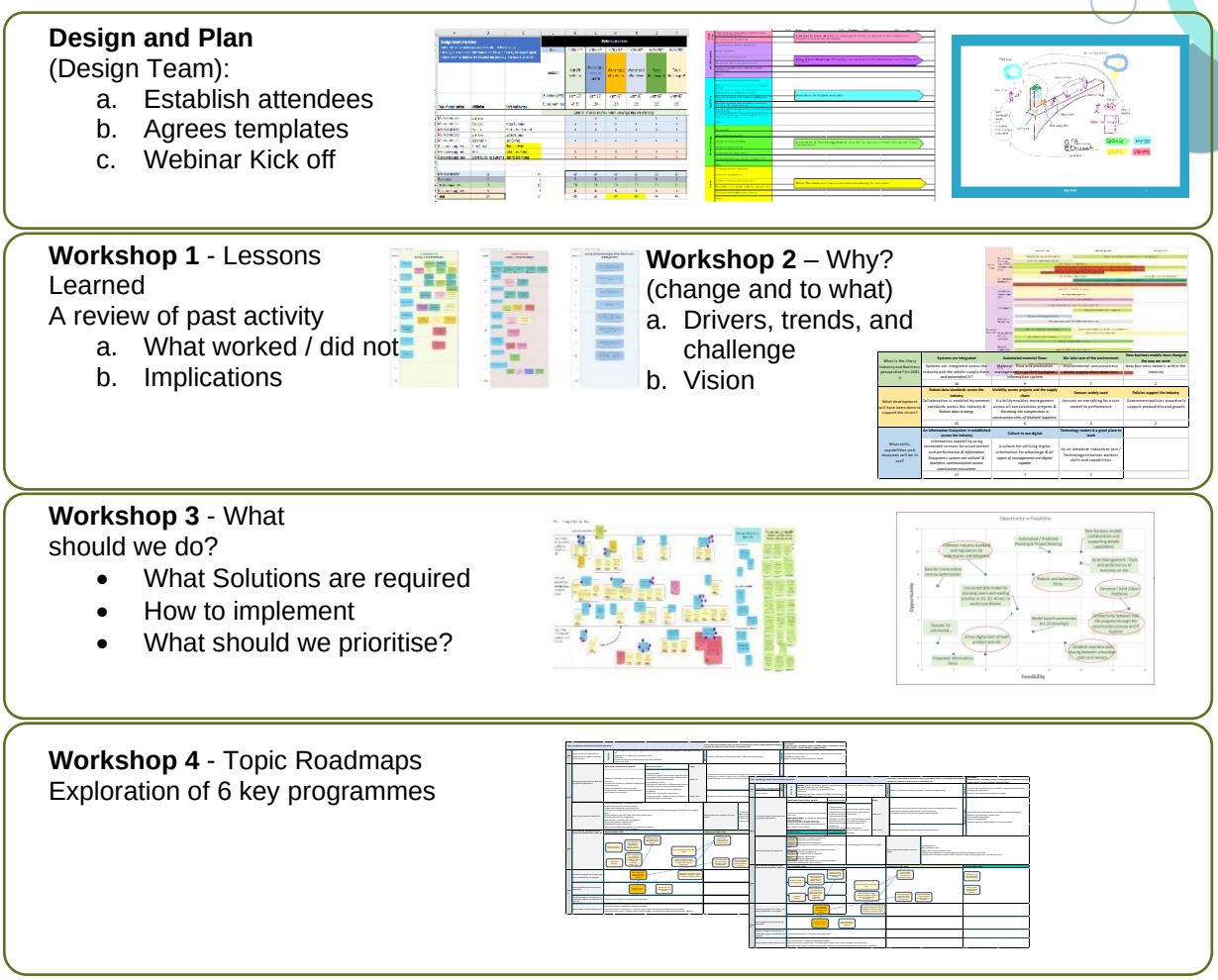


Figure 4 - The process overview

2.5 Workshop Design Team and Delegates

The unique challenge for this project was the recruitment across the industry. Additionally, some delegates are from competing businesses and participation must be included alongside their day-to-day activities. Originally it was planned for approx.15 delegates, with those attending the workshops coordinating content gathered from a larger number of subject matter experts. This approach followed for prework by the larger organisations e.g., NCC, PEAB, and Skanska, however, it was not so easily to coordinate through technology companies or Resource Suppliers. With the priority on inclusion, as this is a Federation, the workshop sessions were extended in numbers and larger amounts of prework data was submitted. In Workshops 1-3 four facilitators were used and three for workshops 4a-b.

Table 3 - Attendance numbers and Design meetings and Workshops

Session	Design (1-3)	Kick off	WS1	Design 4	WS2	Design 5	WS3	Design 6	WS4b	WS 4b
Attendance Delegates		19	21	3	13	3	14	3	14	14
Attendance Design Team	10	9	8	7	7	5	5	6	6	5
Total	10	28	29	10	20	8	19	9	20	19

The total accepted invitations to the project were 33 and 11 Design Team members. Those who participated was 28 and 9, respectively.

2.6 Timeline

Table 4 - Time line

Phase	**Project development**	**Delegate recruitment and Design**	**Kick-off**	**Lessons Learnt**	**Why and Vision**	**What and How**	**Topic Roadmaps**
Timings	Oct - Dec 2020	Jan - Mar 2021	24 March 2021	7 Apr 2021	20 Apr 2021	5 May 2021	18-19 May 2021
Actions	Proposal Scope Design Team	Design meetings: 20/1 28/2 18/2	Webinar and Prework 1 requests	Design meeting 13/4	Design meeting 28/4 and Prework 2 request	Design meeting12/5	

3. Workshop Outputs

3.1 Lesson Learnt

In the past 5 years a series of pilots had been operated for a Connected Construction Site as a test bed project for digitalisation in the construction. Some of the delegates had experience of these projects, however, we also captured knowledge from other digital projects, within the construction industry, drawing upon the experience of all delegates.
The objective of these sessions was not to review the pilots but rather to use the experience gained as a starting point for the project. The outcome was to identify what had been learnt and so far, and specifically the implications to be carried forward into the Roadmapping project.

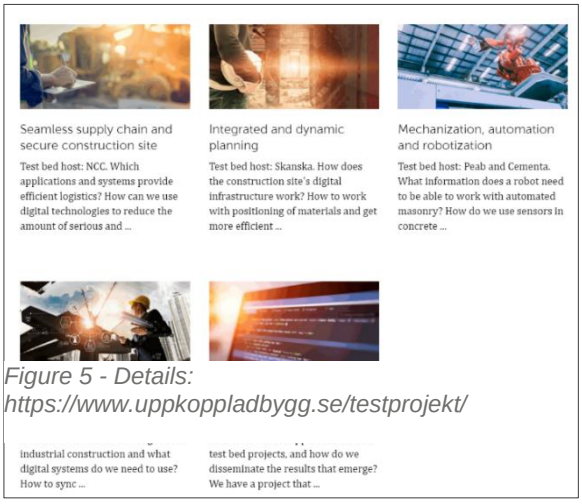


Figure 5 - Details: https://www.uppkoppladbygg.se/testprojekt/

The methodology to undercover this information was to use Retrospective Roadmapping, looking back over the last 5 years.

Prework 1 inputs were collected via prework and then consolidated and clustered in readiness for Workshop 1. Circulated in advance, at the workshop the delegates reviewed and discussed the submissions and clusters, adding any additional information before ‘dot’ voting on the most significant findings.

The workshop discussion focused on three key areas for discussion as a result of the inputs:

1. What enabled these projects that would help in the future?

2. What were the key barriers?

3. What are the implications and key learnings from past experience?

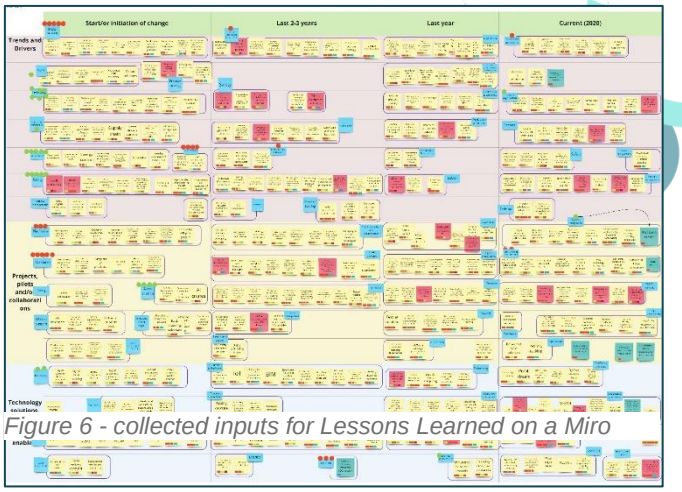


Figure 6 - collected inputs for Lessons Learned on a Miro

The discussions were managed in four subgroups and outputs collated into the significant findings. The details are shown in Appendix C. and further details are included in the files – Appendix A that captures the details of submissions and subgroup discussions. The findings can be further grouped (below):

Table 5 - Lessons Learned summary

Develop industry capability	Use data to demonstrate value	Enable the use of digital
• New business models are needed for development and collaboration (6) • Developing construction industry businesses and people with digital skills and capability (3)	• Seek Productivity improvements (6) • Focus on turning data into value and insight (6) • Consider how Sustainability and the Environment can be enabled by digital (3) • Benefits need to be captured and demonstrated to gain impetus in the industry (3)	• Standards and platforms must enable connected work sites (4) • Safety should be a key focus of developments (3) • Enable developments to include all business sizes and the supporting supply chain (2) • Funding Research is vital for developments (1)

Note: *The 4 subgroups voted on the enablers and barriers and then summarised their recommendations. As a proxy for importance the scores in brackets are the total number of consolidated comments across all groups*

There are several insights that were shared to support the above table e.g., verbatim comments are:

- The digital information is there but the systems rely on paper and people still make gut feel decisions.
- The benefits case is not proven. Productivity improvements have not been shown – but quality has improved.
- Individuals have more digital maturity than companies and this will need leadership to change.

There will need to be a significant change management approach to move from pilots to integrate digital approaches into day-to-day operations.

3.2 Visioning

In workshop 2, and following the roadmap WHY layer session, the Vision session was linked to the reason to change, and the challenge was to help delegates think about what the industry and the people could become in the future.

This was the only time in the process that the delegates were assigned into four subgroups according to their industry type:

- Research – University contributors
- Technology – Suppliers to the industry focussed in delivering digital capability
- Construction Industry – This involved directly in the industry
- Resources Suppliers – Those businesses, who provide goods or services for construction

Before the workshop all the delegates Vision prework was assembled onto four digital whiteboards and the individual inputs clustered ahead of the workshop. This allowed analysis of the cluster perspectives across all four boards. The number of ideas submitted and used in each cluster was used to derive an understanding of the nature of the vision being created.

Table 6 - Prework visioning analysis (numbers represent a proxy for relative importance – number of mentions)

Skills and capabilities	Collaboration across industry	Knowledge and planning	Systems	Technology	Culture	Productivity / lower costs
9 Workforce skills and capabilities	23 Data share via common standards	24 Data used for product, quality and site performance	2 Easy to use on sites	13 Sensors used for more data	11 Management though data visibility	7 Material and production flow automation
4 Digitally capable management	7 New business models	8 Decision support tools		7 Easily connect on sites	6 Proactive safety	3 Dynamically change site layouts
1 Attracting talent	2 Legal frameworks support use of digital	4 Drawings (design to build)		3 Use of Robots	3 Environmental inclusion	1 On-site manufacture and assembly
	1 Government policies support				2 Digitalised industry gets investment	1 Off-site Manufacturing
	1 Researchers can use common data				2 Capture Innovation	

Table 7 - The analysis of inputs

Category	Proportion of inputs
Data, standards, capture and systems	50%
Working in different ways of working	29%
New methods of construction	10%
Industry enablement	11%

The observations were discussed with the Design Team and the challenge was made as to whether the focus should be on the technology or what is needed in the future and how can technology enable this. This led to a review of the scope to ensure that delegates considered what a Vision might include in the workshop session.

This Visioning session was not intended to be a finalisation of terminology, nor one statement, but that each group should develop a clear position that was understood by the others to broaden perspectives during the formulation of the roadmap in 2.4 below.

Table 8 - Vision statements (numbers represent a proxy for relative importance – number of mentions)

Vision questions	Summarised statements				
What is the likely Industry and Business perspective? (in 2031 +)	Systems are integrated	Automated material flows	We take care of the environment	New business models have changed the way we work	We manufacture much more content off-site
	14	9	7	2	2
What development will have been done to support the vision?	Robust data standards across the industry	Visibility across projects and the supply chain	Sensors widely used	Policies support the Industry	
	15	6	3	2	
What skills, capabilities and resources will be in use?	An information Ecosystem is established across the industry	Culture to use digital	Technology makes it a great place to work		
	17	7	7		

In the workshop, the subgroups:

- Examined the inputs made by the subgroup members for the three questions posed in the template
- Considered the clusters, naming and any missing content
- Dot voted for the top clusters that best represented their collective views
- Each group then answered 'what would life look like for a persona after 2031+'

Table 9 - Construction Site Personas defined by the subgroups of workshop participants.

Construction	Researchers	Technology	Resource Supplier
Area Manager or Business Unit Head	A Construction Worker	Project Manager	Sub-Contractor or supplier to site
Information at their fingertips	Great working environment	Efficient allocation of resources	Collaboration across the supply chain
Planning scenarios	Recognised as a high-status worker	Data driven	Project Integration across the supply chain
Flexible working and a great place to work	Planning considers the workers	Proactive approach	Use of Big Data across the supply chain
Client meetings	More outsourcing to specialists	Leadership	
Safety and environmental	We have digital tools for your work	Real and virtual presence on-site	
Off-site construction by new high-tech businesses	We are self-organising		

Note: *The full details for the visioning tables above are shown in Appendix D*

The results show from the personas (Table 9), show change in the industry and that digital has transformed construction to be a place that people can be attracted to and it is recognised as such. It is a place where technology has helped the impact on the environment with the highest levels of safety.

The Vision summarised statement (Table 8) show a different perspective. In this data the focus is on the availability and flow of information across the whole construction supply chain as the

major transformation. These discussions reflect that without knowing how data standards and information can flow, on an open basis, the potential for digital will not be fully realised. This has a very significant impact on inclusion across the industry. The current approach, led by the major businesses, often utilising different technology provider solutions will lead to a fragmented approach particularly affecting the supply chain who may have to adapt to numerous systems.

Digital capability can be instrumental to any business; however, the challenge is not dissimilar to the setting of environmental and safety standards and understanding when coopetition is required.

3.3 Trends, drivers and challenges

The two key questions were posed to gather data on Trends, Drivers and challenges:

- What are the external factors that are driving change in worksites e.g., shortage of labour, safety, legislation etc.
- What are the requirements of the stakeholders e.g., costs drivers, safety, corporate objectives, productivity, or profit improvements?

The purpose is to understand why and when is change needed and the input was structured into the following roadmap layers:

Table 10 - Why roadmap layers

External Drivers • Political, Social, Technology, Legal, Economy, Environment and Safety • Competition e.g., International	**Value Chain Perspectives are:** • Customers (e.g., owners, clients etc.) • Tech Companies • Research and Development • Construction Co / main sub-contractors • Resource suppliers (e.g., materials, people, systems etc.) • Other

The content was captured from workshop participants through a pre-work questionnaire for short (2022-2025), medium (2026-2030) and long term (2031+) and 22 responses were received (80% of those at the Kick-off webinar)

Participants submitted a total of 188 ideas which were summarised into 31 idea-statements. A summary table of Trends and Drivers and were circulated to workshop participants as pre-read material. During workshop 2, participants reviewed the clusters and their ideas adding 7 additional ideas. Following the workshop delegates were given 5 votes to prioritise the most relevant ideas.

Table 11 - Top Drivers, trends and challenges as voted by delegates

Votes per topic	Drivers, Trends and Challenges
20	Lower production costs / Increased productivity
20	Reduced CO2 emissions and sustainability
17	Supply chain development and productivity
13	Customer and new generation employees create demand for the use of digital technology (and for later use) e.g., digital twins
11	Digital capability improves quality and product performance
7	Safer working enforced by legislation
7	Low profitability in the construction industry (low margins resulting to little innovation)
6	New collaborations change the industry
5	Increased competition from International construction companies
4	Attract talent to the Industry
4	Increasing data use for management
4	Sweden Industry competitiveness (and flexibility)
4	New digital focussed Competitors

There was no surprise that productivity should rank so highly, however, the discussions highlighted that in recent times and increasingly a perquisite of any major project, was the direct influence of the customer on the sustainability agenda, Integrated digital approaches and safety.

Participants suggested that the government should enact new legislation to increase the reduction pace of CO2 emissions as customer demand is not yet consistent nor communicated and coordinated throughout the value chain. There was a discussion on the interrelation of emissions and energy consumption, and control of both are important for achieving environmental sustainability. It was suggested that buildings should adhere to environmental standards in a cost-effective manner to reduce impact on affordability.

From a construction industry perspective, especially inner-city sites, space shortage was also identified and that integration with the supply chain was essential. Collaborative platforms were suggested in the sphere of productivity, productivity, environment, and safety and the implementation of robotics and autonomous systems. This can be achieved through integrating information and digitisation. Digital data sharing can enable better collaboration and supply chain integration between different industrial actors. Harmonisation of digital resources across SMEs and Large companies was also suggested.

The push to ‘zero climate impact’ can be supported through smart technology, such as AI for an early-stage climate control solution. This is also linked to the use of digital technology to ensure the construction sector has a highly comparable capability with international competition. Essential to this are digitally talented people within the industry, particularly the younger generation, who may not view the construction industry as a place for a digital career. Automation and digitalisation projects will help with recruitment.

Finally, it was acknowledged that proposed digital experiment should fit both project and company strategy perspectives and prove the value and benefits.

The associated timescales for the drivers can be found in Appendix E1 and an analysis of the voting patterns in Appendix E2.

3.4 Solutions (What) and prioritisation

At this stage of building the roadmap the delegates were responding to the Why layer by establishing What solutions ideas could be considered (see workshop 3 in figure 4 – section 2.4 above and appendix J). Again, the content for potential solutions was captured from workshop participants through pre-work templates and participants were asked for their ideas in the following solution (What) categories:

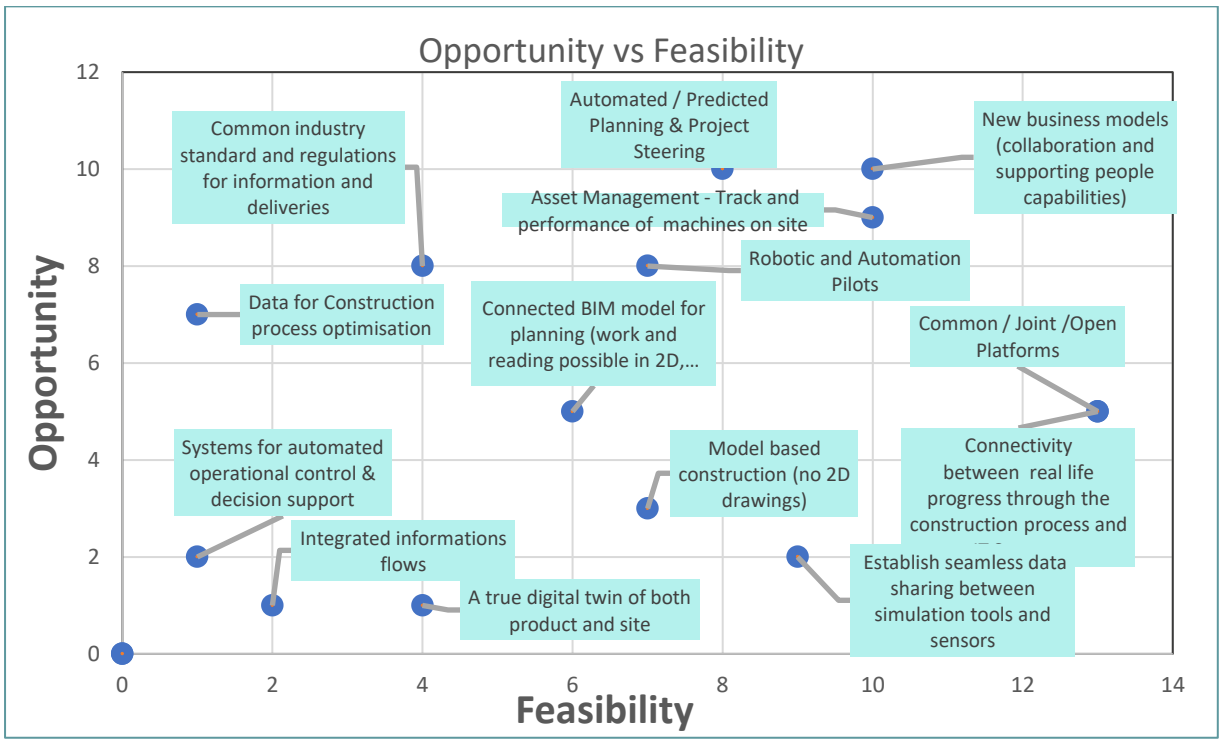
Table 12 - Roadmap What layer categories

What categories
• Production automation e.g., Robotics etc. • Planning and control of production (inc quality & safety) • Industry-wide modelling commonality • Measurement and control systems (collection of data) • Simulation/training systems (safety, operations etc..) e.g., VR, Digital twins etc. • Site operations configuration (APD situation layout) and planning • Construction Supply Chain management e.g., to site, from site, on-site • Others

A total of 11 consolidated prework responses were received and grouped for Workshop 3. In the workshop, three facilitated groups discussed and reviewed the clustered ideas and titles. Furthermore, new thoughts were also captured.

The next stage in the process is to understand which Solutions should be prioritised and become candidates for further exploration via Topic Roadmapping. The approach is to compare the Opportunity a solution creates, or its impact and then contrast that with the Feasibility of making it happen. The review and discussion in the workshop using the Miro boards then prepared the delegates to consider the criteria for their voting of Opportunity and Feasibility.

Table 13 - Results of the Opportunity and Feasibility voting at Workshop 3



The process was that delegates considered the criteria before rating ideas for opportunity and then for feasibility e.g., ideas with no opportunity are not rated for feasibility.

The Design Team crafted and reviewed the criteria for the ratings below.

Table 14 - Criteria for Opportunity and Feasibility

Opportunity	Feasibility
Which ideas have the highest impact in the longer-term for the Construction Industry to: • Improve Productivity? • Make a difference to the Sustainability* agenda within the Industry? • Creates a safe working environment.	Which ideas are the most feasible for the Construction Industry? • Can the technology be easily developed or acquired to provide a solution for this idea • Can organisations implement the solution including the necessary digital transformation

Note: Sustainability also includes Environmental; and the Circular Economy

The solutions that received the highest opportunity votes were new Business Models (collaboration and supporting people capabilities) and Automated / Predicted Planning & Project Steering. Under these two categories the following noteworthy ideas were submitted by participants:

- Totally integrated planning
- Self-learning planning system based on AI, evaluate on KPI's connected to planning-ability
- Model, quantities, location planning and cost connected
- Planning of concrete operations are updated in real-time, predictions of future state are based on latest sensor data,
- Seamless integrated design, planning and production
- New business models

Ideas that receive the top feasibility votes were Common / Joint /Open Platforms and Connectivity between real life progress through the construction process and IT Systems.

Common / Joint /Open Platforms were discussed in terms of common databases and trusted ownerships across the industry. It was suggested that all solutions to be scalable and easy to set up for new projects and that data to be used was on an aggregated level.

Examples of the key messages for connectivity:

- 3D design refined along constructions process
- Connected Information
- Connectivity between real life progress and IT Systems
- Connection of model, quantities, location planning and cost
- Need to digitally combine plan, model- and progress data for real-time follow-up
- 3D design with phase classification together with supplier at an early stage
- Real-time field reporting (by connecting and tracking materials, equipment, and, most importantly, workers at the construction site)
- Demonstrate an integrated method for planning and control of concrete operations incl. feedback to suppliers
- Model, quantities, location planning and cost connected
- Risk that the lead times of governing bodies reduce the possibility of early involvement with suppliers e.g., designing safe solutions.

3.5 Technology and Resources (How)

In this roadmapping layer, participants were asked to present ideas in response to the question “How will the solution be developed?”. A pre-work template was used to capture information and the linkage to the solution Roadmap layer:

Table 15 - Roadmap What layer categories

Innovation & Technology: • Connectivity • Materials & components • Design tools and modelling • Manufacturing processes • Construction & site processes • AI, Big Data & IoT (inc. devices, software etc.) • Other	**Enablers:** • Communication & Awareness • Standards & Regulation • Facilities & Infrastructure & Finance • Capabilities (inc. digital) / skills (inc. education) • Partnerships & Collaboration / Unions • Other

Participants were asked to present their ideas under above categories, in workshop 3. Facilitated in 3 groups, collated information was presented and reviewed. The opportunity was given to move ideas position to other sub-layers or change the clusters and their titles. The final stage information from the three groups was combined to develop a single to ensure coordination across the subgroups. The Ideas can be seen in appendix G and have been further structured in the following table.

Table 16 - How approaches (with more than 2 linkages to the What layer)

AI, Big Data & IoT (inc. devises, software etc.)	Capabilities (inc. digital) / skills (inc. education) inc	Communication & Awareness	Connectivity	Construction & site processes
Cloud services to enable real-time visualisation and editing of data, also access via mobile devices	Build people, organisational and change capabilities, and secure knowledge capacity	Each part understands the roles in the supply chain	Track and trace	Data collection to plan and control (AI)
Dog robots and similar tech	Developing, adopt and implement standards and regulations regarding maturity (MMI) in models, planning	Show client the possibilities with digitalization	New ecosystem, comprises of IoT, cloud, edge computing, and Next-Generation Networks	A dynamically optimized construction site layout (digital APD plan)
Drones for measurements	Common standards and regulations for digital solutions		Affordable and reliable connectivity solutions on main parts of 99 % of the sites	No paper processes/Trusted decisions
Develop smart algorithms to support operational decisions based on sensor data	Learnings from other industries using LEAN		Productify connectivity 'in a box' for easy connection of construction sites Inc. business model	Process focused and not project focused
Robotics in complex tasks	New ecosystem, comprises of IoT, cloud, edge computing, and Next-Generation Networks			Development of robots for diff parts of the construction process
	Focus on Big data resources			Digital Modelling
				Operational process refinement

Design tools and modelling	Facilities & Infrastructure & Finance	Manufacturing processes	Partnerships & Collaboration / Unions	Standards & Regulation
Digital twins of the construction site	Business models for supplier of robotic services	Prefabrication on construction site for selected parts	Collaboration between construction companies & supplier & tech companies and Unions	Open standards agreed by sector
Governance Status Management BIM Objects		Sensors and tagging (where are materials and tools)	Business model	Establish legal and regulations on data ownership
Develop tools to make to connect model, quantities, location planning and cost in an easy way to use		Higher usage of components and materials suitable for prefabrication		Cooperative business models and frameworks
VR/AR		IoT/tagged material, components /equipment		Open access APIs and standards between planning systems and organisations
BIM and Digital Twins				
Integrated planning for construction and manufacturing				

References to WHAT layers were suggested in the areas of Standards & Regulation, Skills, Partnership & Collaboration, and Connectivity. Participants suggested refinement and improved implementation of existing standards through various digital enablers, such as GTIN, QR codes

and data templates. For standards development, sectoral agreements were important foundations to include wider collaboration among industry actors, including customers.

Leadership is needed, particularly in the sphere of change management and a broader level of digital competencies was suggested. Dissemination of information regarding the benefits of AI in construction was also emphasised along with educating staff, contractors, and suppliers.

On partnership and collaborations, a transparent approach is considered significant. An early-stage collaboration was suggested, particularly around deployment of technology such as Digital twins. Discussion with Unions should also cover digital adoption at workplaces.

Connectivity is a key enabler to develop digital solutions between different regardless system of location to allow the application of technologies, including sensors and other data capture devices, connectors, tracking software, cameras, robots etc.

3.6 Linkage Grids

The Roadmap also captures the link between Trend and Drivers (Why), Solutions (What) and Technology and Resources (How). Participants during the second pre-work were asked to make the linkages and these are shown on the linkage tables 15 & 16 below.

The linkages grids also allow for several considerations for the future use of the Landscape e.g.:

- If there is a change in trend, what will it affect?
- What technologies are grouped and can be leveraged by solutions?
- What are the dependencies?

Table 17 -Trends and Drivers vs. Solutions

Trends and Drivers																				Linkage Grid	
Lower production costs / Increased productivity	Reduced CO2 emissions and sustainability	Supply chain development and productivity	Customer and new generation employees create demand for the use of digital technology (and for later use) e.g. digital twins	Digital capability improves quality and product performance	Safe working enforced by legislation	Attract talent to the Industry	Increased competition from International construction companies e.g. China etc	New collaborations change the industry	Increasing data use for management	Low profitability in the construction industry (low margins resulting to little innovation)	Sweden Industry competitiveness (and flexibility)	New digital focussed Competitors	Utilisation of technology development	Construction leadership for digital adoption	Government push for Digitalisation	Data protocols, standards and management	Customers requiring project and cost transparency	Development of Technology companies focussed on construction	Remote working capability (e.g. covid)		
TD01	TD02	TD03	TD04	TD05	TD06	TD07	TD08	TD09	TD10	TD11	TD13	TD14	TD15	TD16	TD18	TD19	TD20	TD21	TD25	Solutions (What)	
																				11	Robotic and Automation Pilots
																				10	Connectivity between real life progress through the construction process and IT Systems
																				6	Automated / Predicted Planning & Project Steering
																				7	Data for Construction process optimisation
																				2	Model based construction (no 2D drawings)
																				13	Common / Joint /Open Platforms
																				7	Common industry standard and regulations for information and deliveries
																				4	Systems for automated operational control & decision support
																				8	A true digital twin of both product and site
																				7	Connected BIM model for planning (work and reading possible in 2D, 3D, 4D etc) in world coordinates
																				4	Establish seamless data sharing between simulation tools and sensors
																				5	Integrated informations flows
																				3	Asset Management - Track and performance of machines on site
																				8	New business models (collaboration and supporting people capabilities)
11	10	13	9	12	7	1	2	10	3	1	1	2	1	3	1	3	1	2			

Notes for both linkage chart grids:

- *Trends are in pink colour, solutions in yellow and technology/enablers in blue colour*
- *The values in the pink vertical column are the number of linkages to trends and drivers (above)*
- *The values in the blue vertical column are the number of linkages to Technology (below)*

The majority of Solutions (What) corresponds to the following key Trend and Drivers (Why):

- Lower production costs / Increased productivity
- Reduced CO2 emissions and sustainability
- Supply chain development and productivity
- Customer and new generation employees create demand for the use of digital technology (and for later use) e.g., digital twins
- Digital capability improves quality and product performance

Similarly, solutions (What) is also compared to Technology and Resources (How) in the following table:

Table 18 - Solutions vs. How ideas (technology and resources)

Linkage Grid		Productify connectivity 'in a box' for easy connection of construction sites Inc. business model	Sensors and tagging (where are materials and tools)	Digital twins of the construction site	Data collection to plan and control (AI)	Each part understand the roles in the supply chain	Open standards agreed by sector	Build people,organisational and change capabilities and secure knowledge capacity	Collaboration between construction companies & supplier & tech companies and Unions	Track and trace	Cloud services to enable real-time visualisation and editing of data, also access via mobile devices	Show client the possibilities with digitalization	Establish legal and regulations on data ownership	Developing, adopt and implement standards and regulations regarding maturity (MMI) in models, planning	Develop tools to make to connect model, quantities, location planning and cost in an easy way to use	No paper processes/Trusted decisions	Dog robots and similar tech	Common standards and regulations for digital solutions	Drones for measurements	New ecosystem, comprises of IoT, cloud, edge computing, and Next-Generation Networks	IoT/tagged material, components lequipment	BIM and Digital Twins	Develop smart algorithms to support operational decisions based on sensor data	New ecosystem, comprises of IoT, cloud, edge computing, and Next-Generation Networks	Digital Modeling	Focus on Big data resources	Operational process refinement	Affordable and reliable connectivity solutions on mainparts of 99 % of the sites	Integrated planning for construction and manufacturing	Open access APIs and standards between planning systems and organisations
Solutions (What)																														
Robotic and Automation Pilots	17		■		■		■		■		■					■	■	■	■			■	■					■	■	■
Connectivity between real life progress through the construction process and IT Systems	20	■	■	■	■	■	■	■	■	■	■			■				■	■		■	■		■		■		■	■	■
Automated / Predicted Planning & Project Steering	17			■	■		■	■	■	■			■		■					■	■		■		■			■	■
Data for Construction process optimisation	14				■	■	■	■	■		■			■		■	■	■	■							■	■			
Model based construction (no 2D drawings)	4	■											■			■												■		
Common / Joint /Open Platforms	16				■	■	■	■	■		■	■	■	■				■				■		■		■	■			■
Common industry standard and regulations for information and deliveries	17			■	■	■	■	■	■		■	■		■	■	■		■				■	■			■	■			
Systems for automated operational control & decision support	12		■		■		■		■	■	■		■				■					■		■						
A true digital twin of both product and site	9			■										■	■					■	■	■	■		■					■
Connected BIM model for planning (work and reading possible in 2D, 3D, 4D etc) in world coordinates	12			■	■	■	■								■	■						■		■	■	■				■
Establish seamless data sharing between simulation tools and sensors	13		■		■		■						■	■	■			■			■		■		■			■		■
Integrated informations flows	14				■	■	■	■	■		■	■		■	■			■						■	■	■	■			
Asset Management - Track and performance of machines on site	9					■	■			■	■				■				■		■								■	■
New business models (collaboration and supporting people capabilities)	13	■			■	■			■		■		■		■	■				■	■									
		3	4	5	11	8	11	6	9	4	9	3	6	7	8	6	3	7	4	3	6	7	5	5	5	6	4	5	4	8

Analysis of the linkages between Solutions (What) and Technology and Resources (How) shows there is the potential for leverage across several themes (table 17 below) are:

- Open standards
- Business models
- Modelling

Other themes include:

- Connectivity / Cloud systems / Data collection
- Stakeholder management e.g. Unions
- Connectivity between real-life progress through the construction process and IT Systems
- Robotic and Automation Pilots
- Automated / Predicted Planning & Project Steering
- Common industry standard and regulations for information and deliveries

Technology and resources	Potential themes
Productify connectivity 'in a box' for easy connection of construction sites Inc. business model	**Business models**
Sensors and tagging (where are materials and tools)	
Digital twins of the construction site	**Modelling**
Data collection to plan and control (AI)	

Table 19 - Related technologies in the linkage grids	
Open standards agreed by sector	Open Standards
Build people, organisational and change capabilities and secure knowledge capacity	
Collaboration between construction companies & supplier & tech companies and Unions	
Track and trace	Open Standards
Higher usage of components and materials suitable for prefabrication	
Governance Status Management BIM Objects	Open Standards
A dynamically optimized construction site layout (digital APD plan)	
Cloud services to enable real-time visualisation and editing of data, also access via mobile devices	Open Standards
Show client the possibilities with digitalisation	Business models
Establish legal and regulations on data ownership	
Developing, adopt and implement standards and regulations regarding maturity (MMI) in models, planning	Open Standards
Business model	Business models
Develop tools to make to connect model, quantities, location planning and cost in an easy way to use	Modelling
No paper processes/Trusted decisions	
Dog robots and similar tech	
Common standards and regulations for digital solutions	Open Standards
VR/AR	
Process focused and not project focused	
Drones for measurements	
Development of robots for diff parts of the construction process	
Learnings from other industries using LEAN	
New ecosystem, comprises of IoT, cloud, edge computing, and Next-Generation Networks	Open Standards
IoT/tagged material, components /equipment	Open Standards
BIM and Digital Twins	
Digitalising workplace	Open Standards
Develop smart algorithms to support operational decisions based on sensor data	Modelling
Business models for supplier of robotic services	Business models
New ecosystem, comprises of IoT, cloud, edge computing, and Next-Generation Networks	Business models
Prefabrication on construction site for selected parts	
Digital Modelling	Modelling
Focus on Big data resources	
Operational process refinement	
Affordable and reliable connectivity solutions on main parts of 99 % of the sites	
Integrated planning for construction and manufacturing	Open Standards
Robotics in complex tasks	
Cooperative business models and frameworks	Business models
Open access APIs and standards between planning systems and organisations	Open Standards

3.6 Landscape Roadmap

Table 20 - Complete view of the Strategic Landscape

Landscape			ST (2022 - 2026)	MT (2026 - 2030)	LT (2031 - 2040)
Trends and Drivers	External drivers	Political, Social, Technology, Legal, Economy, Environment and Safety	Safe working enforced by legislation		
			Government push for Digitalisation		
			More and affordable housing / buildings	Circular economy (Waste and Water) recyling / reuse re-process	
			Remote working capability (e.g. covid)	Copyright - Legal terms eg. a model	
				New bank initiative will increase focus on sustainability and efficient work sites to get favorable bank terms	
				Lack of construction site workers	
		Competition e.g. International	Increased competition from International construction companies e.g. China etc		
				New digital focussed Competitors	
	Value chain Perspectives	Customers (e.g. owners, clients etc..)	Reduced CO2 emissions and sustainability		
			Customer and new generation employees create demand for the use of digital technology (and for later use) e.g. digital twins		
			Customers requiring project and cost transparency		
		Tech Companies	Utilisation of technology development		
			Availability of (also advanced) technology and expectations to be able to use it..		
			Data protocols, standards and management		
			Development of Technology companies focussed on construction		
		Research and Development	Ability to create a good Ideation/ mass collaboration culture/ "fail-fast" approach		
			Data capture enables more Research for construction industry		
		Construction Co / main sub-contractors		Digital capability improves quality and product performance	
			Increasing data use for management		
			Sweden Industry competitiveness (and flexibility)		
			Construction leadership for digital adoption		
		Resource suppliers (e.g. materials, people, systems etc.)	Supply chain development and productivity		
			Suppliers and their deliveries become Net Zero		
		Other	Attract talent to the Industry		New collaborations change the industry
			Low profitablity in the construction industry (low margins resulting to little innovation)		
				Changing work force	
Solutions (What)	Products	Production automation e.g. Robotics etc.	Robotic and Automation Pilots		
		Planning and control of production (inc quality & safety)	Connectivity between real life progress through the construction process and IT Systems		Data for Construction process optimisation
			Automated / Predicted Planning & Project Steering		
		Industry wide modelling commonality	Model based construction (no 2D drawings)		
		Measurement and control systems (collection of data)	Common / Joint /Open Platforms	Systems for automated operational control & decision support	
			Common industry standard and regulations for information and deliveries		
		Site operations configuration (APD situation layout) and planning		A true digital twin of both product and site	
				Connected BIM model for planning (work and reading possible in 2D, 3D, 4D etc) in world coordinates	
		Construction Supply Chain management e.g. To site, from site, on site	Establish seamless data sharing between simulation tools and sensors	Integrated informations flows	
			Asset Management - Track and performance of machines on site		
		Others	New business models (collaboration and supporting people capabilities)		
Technology and Resources	Innovation & Technology	Connectivity	Track and trace	New ecosystem, comprises of IoT, cloud, edge computing, and Next-Generation Networks	Affordable and reliable connectivity solutions on mainparts of 99 % of the sites
		Materials & components	Sensors and tagging (where are materials and tools)	IoT/tagged material, components/equipment	
			Higher usage of components and materials suitable for prefabrication		
		Design tools and modelling	Digital twins of the construction site		
			Governance Status Management BIM Objects		
			Develop tools to make to connect model, quantities, location planning and cost in an easy way to use		
			VR/AR	BIM and Digital Twins	
					Integrated planning for construction and manufacturing
		Manufacturing processes		Prefabrication on construction site for selected parts	
		Construction & site processes	Data collection to plan and control (AI)	Digitalising workplace	
			A dynamically optimized construction site layout (digital APD plan)	Digital Modelling	
			No paper processes/Trusted decisions	Operational process refinement	
			Process focused and not project focused		
			Development of robots for diff parts of the construction process		
		AI, Big Data & IoT (inc. devises, software etc.)	Cloud services to enable real-time visualisation and editing of data, also access via mobile devices	Develop smart algorithms to support operational decisions based on sensor data	Robotics in complex tasks
			Dog robots and similar tech		
			Drones for measurements		
	Enablers	Communication & Awareness	Each part understand the roles in the supply chain		
			Show client the possibilities with digtalization		
		Standards & Regulation	Open standards agreed by sector		Cooperative business models and frameworks
			Establish legal and regulations on data ownership		Open access APIs and standards between planning systems and organisations
		Facilities & Infrastructure & Finance		Business models for supplier of robotic services	
		Capabilities (inc. digital) / skills (inc. education) inc	Developing, adopt and implement standards and regulations regarding maturity (MMI) in models, planning	Build people, organisational and change capabilities and secure knowledge capacity	
				New ecosystem, comprises of IoT, cloud, edge computing, and Next-Generation Networks	
			Common standards and regulations for digital solutions	Focus on Big data resources	
			Learnings from other industries using LEAN		
		Partnerships & Collaboration / Unions	Collaboration between construction companies & supplier & tech companies and Unions		
			Business model		

4. Topic Roadmapping

The Design Team meet to consider the results in section 3.4 Table 13 and apply judgement on which solutions would be explored further during the Topic Roadmapping workshops (4A and 4B in section 2.4 above). IfM provided information to assist in the context of these choices:

- What is appropriate for the Federation?
- What enables the Industry and 'raising the game'?
- What creates the basis for innovations?
- Does it consider supply chain and SME?
- What are critical enablers? e.g. Open standards
- Consider Quick wins and longer-term and the required balance
- The practicalities for sponsoring members

The information from the linkage grids was also used to consider how topics can be used to maximise impact before the Design Team finalised their choices, the scope, and the justification in the table below.

Table 21 - Topic Roadmapping selection

	Title	Scope	Justification
A1	**Developing common data standards/regulations**	Data standards across the industry (and supply chain) to enable digital development covering any material or asset used on a construction site	This will create a basis for other applications and to enable digital developments
A2	**Model based construction using 3 D as the legal document**	From Design/production plans through supply to the construction site	This will create a basis for other applications
A3	**Use of digital twins demonstrators**	For the product and site – models for improvements to environmental and safety performance	Can we find and explore this costly technology by working collaboratively
B1	**Common / Joint /Open Platforms**	How to share data e.g., 'up to date' versions of EPD and Safety Data sheets	This will create a basis for other applications
B2	**Robotic and Automation Pilots**	To develop demonstrators for a wide variety of robotic or automation systems that eliminate repetitive/time consuming/safety risk jobs	Can we find and explore this costly technology by working collaboratively
B3	**Connectivity and agreed data standards for data flows between construction process and IT Systems**	Easy setup of cost competitive connectivity across a site in which multiple suppliers and connected devices can quickly establish.	To establish a seamless flow of data between sensors and IT

The Design group also customised the Topic roadmap template in recognition that:

- The federation programmes work on the basis of consensus
- That change management challenges are significant

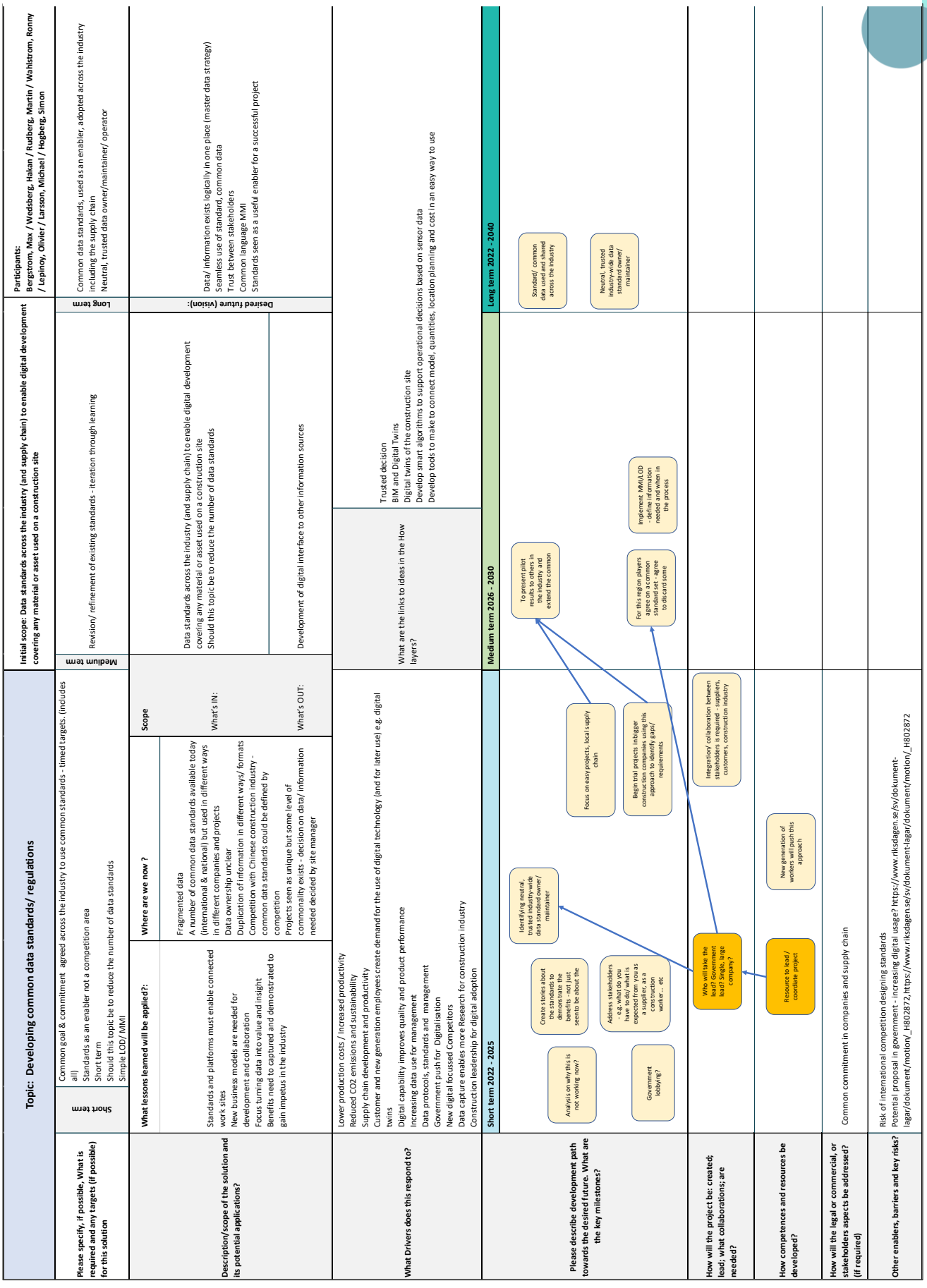
The results of these changes were applied to the step 4 (How layer) e.g. How will the project be: created; lead; what collaborations; are needed?

The selected topics were the addressed in three parallel sessions: A1-3 in workshop 4A; and B1-3 in workshop B, which permitted delegates the opportunity to be in two sessions overall. The Design Team made recommendations on subgroup elections and delegates were given a final choice.

The resulting topic roadmaps are shown in section 4.2 to 4.7. Additionally, during the construction of the topic roadmaps delegates validated the links between the Trends and Drivers and Challenges and the How layer. The result is a consolidated Topic Road map in section 4.8.

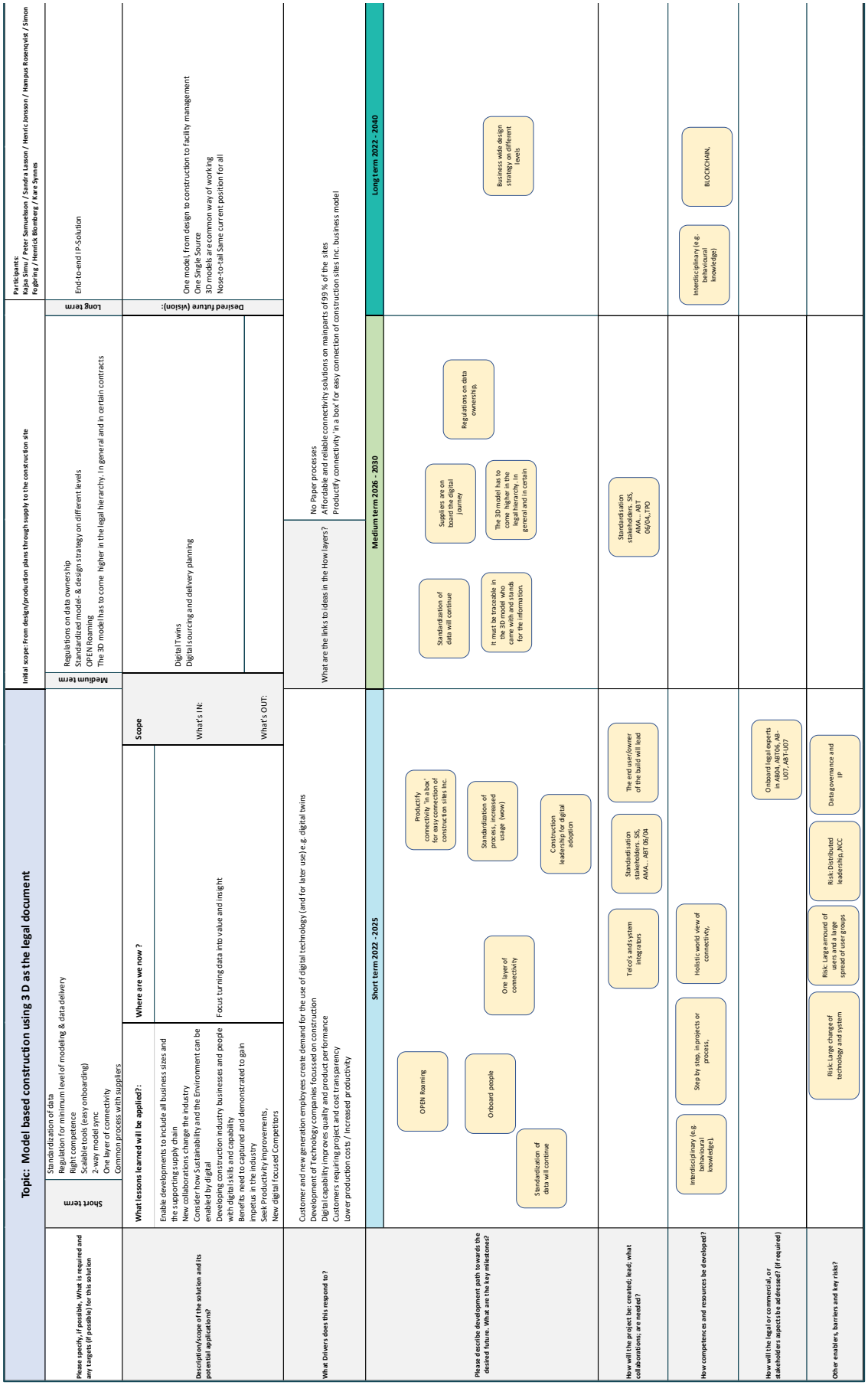
4.1 Common Standards

Table 22 - Topic roadmap - common standards



4.2 Modelling

Table 23 - Topic roadmap - Modelling



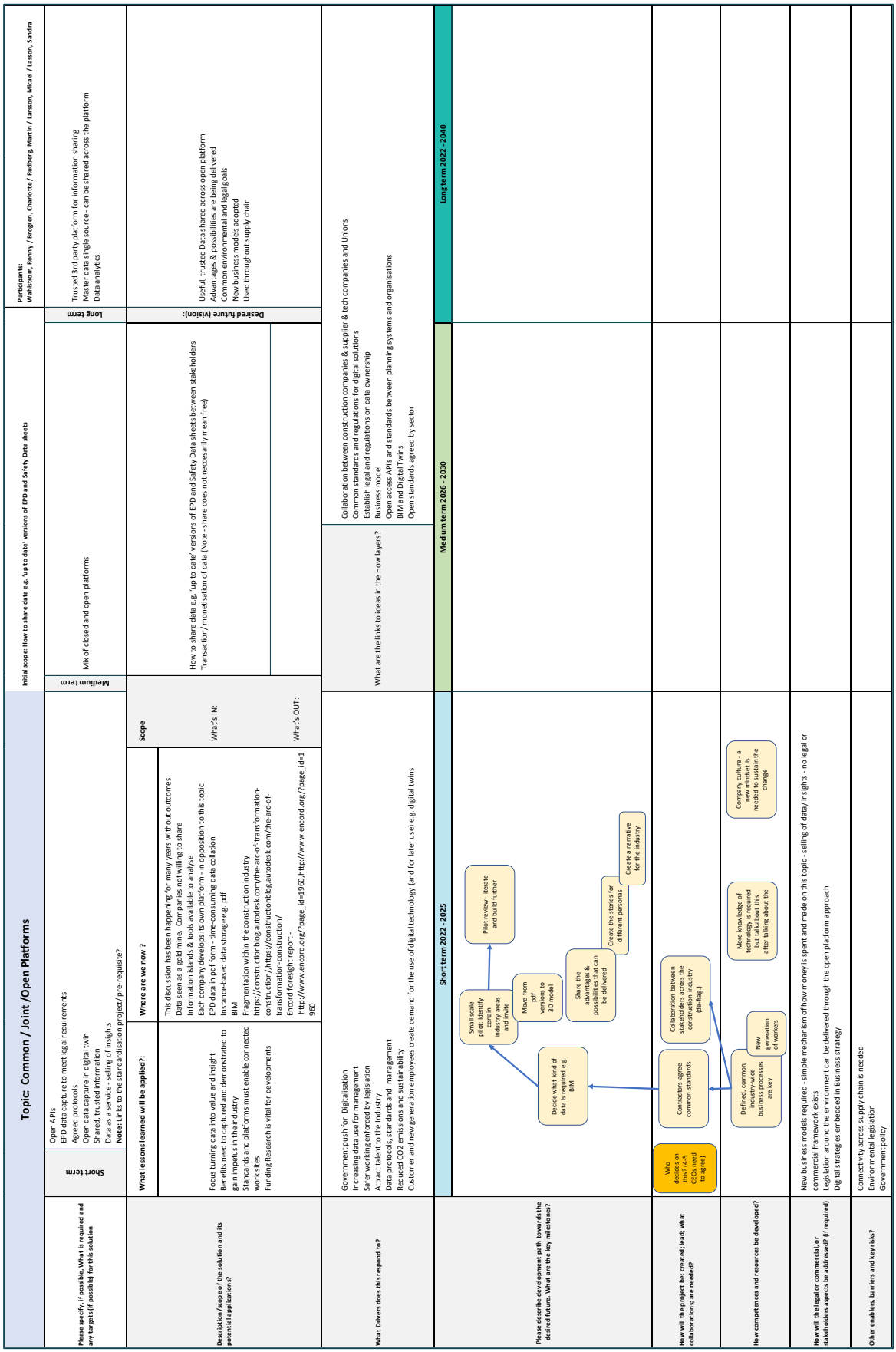
4.3 Digital Twins

Table 24 - Topic roadmap Digital Twins

Topic: Use of digital twins demonstrators			**Initial scope: For the product and site – models for improvements to environmental and safety performance**		**Participants:** Horestrand, Martin / Tofalvi, Ina / Bergsten, Anna / Stehn, Lars / Wikstrom, Karin
Please specify, if possible, What is required and any targets (if possible) for this solution	**Short term**	Demonstrator for CO2 and water reduction Demonstrator for monitoring progress and monitoring of hazardous work areas Visualisation of production progress Higher quality and less errors, which contributes to reducing the climate impact Visualisation/risk analysis for work safety Optimization of energy use on site Simulate and identify safety risks on site Identify material need on site in modular building - reduce material movement on site, material usage and transportations	**Medium term**	Simulate outcome of CO2 emission depending on materiel choose Opportunity to be able to detect and predict dangers via AI Basis for bill of resources, related database with EPD Opportunity to follow the development and progress on the construction site in real time Proactive construction planning with on-line data	**Long term**	As built documentation
Description/scope of the solution and its potential applications?	**What lessons learned will be applied?:** Benefits need to captured and demonstrated to gain impetus in the industry Developing construction industry businesses and people with digital skills and capability Focus turning data into value and insight Focus on ease of use on construction site	**Where are we now ?** Prototypes of digital models are currently being used within R&D projects demonstrating parts of the process and testing technology and data capture	**Scope** What's IN: What's OUT:	Site work and planning is totally model based Predict and prevent incidents and fatalities Model-based construction, no drawings Creating trust in plans made and ease of keeping them up to date Industry and people have collaborated and changed to make this happen Digital maturity so that people on site get the benefits enables full overview on / off site We visualized, optimized, simulated, monitored and predicted work on site significantly deduced environmental impact and no accident occurred Development of digital interface to other information sources	**Desired future (vision):**	Universal system that is easy to connect to and handles the cost of it Several suppliers of the system build to a universal access (e.g. not dominated by proprietary system) It must enable real-time data transmission (demands will increase)
What Drivers does this respond to?	Supply chain development and productivity Construction leadership for digital adoption Remote working capability (e.g. covid) Reduced CO2 emissions and sustainability Digital capability improves quality and product performance		What are the links to ideas in the How layers?	Trusted decision BIM and Digital Twins Digital twins of the construction site Develop smart algorithms to support operational decisions based on sensor data Develop tools to make to connect model, quantities, location planning and cost in an easy way to use		
Please describe development path towards the desired future. What are the key milestones?	**Short term 2022 - 2025**		**Medium term 2026 - 2030**		**Long term 2022 - 2040**	
	People and management	Establish value of digital twins for industry Training and awareness Decision support				
	Technology	Create a mechanism to share current and future experience across the major companies Methods for data collection connection between BIM and Data Use of BIM Information needs for each phase in the construction process is established larger demonstrators Regular use if of DT in large projects Wider variety of commercial digital Twin systems consolidated digital Twins in market Construction based models (similar to: Collaboration between larger construction companies an the Find a way to go from demonstrators to industry wide use				
	Industry engagement	Build case for using open standards Model of data ownership (owned by the building?) Interface between design and construction Interface between Construction and Facilities				
How will the project be: created; lead; what collaborations; are needed?	Sector wide R&D programs för technology development and testing, for effects validations, for developing standards, for evaluating legal aspects and for demonstrations Create prerequisites to create test bed projects (connections between companies, funding) Ready-to-build models New/supplemented role - Digital Process Managers The Building Owners can be a force for change					
How competences and resources be developed?	Research supported development of capabilities and competences for digital twins Involve the end users and keep focus on ease of use,,					
How will the legal or commercial, or stakeholders aspects be addressed? (if required)	Federations such as Byggföretagen and Installationföretagen has role to play					
Other enablers, barriers and key risks?	We need digitally managed building permits Research funding Show value with Digital Twins Main barriers; - data ownership - who can work with the models - prove financial benefits Ownership of data					

4.4 Common Platforms

Table 25 - Topic roadmap Common Platforms



4.5 Robotic

Table 26 - Topic Roadmap - Robotic

Topic: Robotic and Automation Pilots+C2:M15

Initial scope: To develop demonstrators for a wide variety of robotic or automation systems that eliminate repetitive/time consuming/safety risk jobs

Participants:
Kajsa Simu / Hakan Wedsberg / Joakim Jeppsson / Peter Samuelsson / Henrick Blomberg /Hampus Rosenqvist / Micael Thunberg

Please specify, if possible, What is required and any targets (if possible) for this solution

Short term	Medium term	Long term
We need to do pilots to build trust for the information in the model that is used for the robotics on site. More knowledge of automation in design process. MOre detailed information in models. Identify suitable tasks for automation with a business case. Identify what kind of robots are needed and what information is needed to operate that robot/automation. Learn from car industry.	Create understanding of the construction industries needs. Close collaboration with robot suppliers. Digitalize information from drawings so they can easily collect them into BIM models. Robots will handle loading and distribution inside the construction site. Have robots connected to AI that can examine the progress regularly and follow up on the planned schedule.	Data from design tools used to control robots and machinery. Construction process simulated, safety productivitiy optimisation. 24/7 work in our construction sites without physical supervision. Let the automation/robots learn e.g. the usage/quanitity of materials and update future material plats/forecasts. Robots and people working together on sites.

Description/scope of the solution and its potential applications?

What lessons learned will be applied?:	Where are we now ?	Scope	Desired future (vision):
Seek Productivity improvements. Enable developments to include all business sizes and the supporting supply chain. Funding Research is vital for developments. Robot/automation industry lacks understanding of business models, provide wrong solutions. Safety should be a key focus of developments. Consider how Sustainability and the Environment can be enabled by digital. Large companies are quite busy and overwhelmed to pump in resources on Robotic projects - Start ups need to take lead. New business models are needed for development and collaboration. Benefits need to captured and demonstrated to gain impetus in the industry. Standards and platforms must enable connected work sites.	Where are we now (has anyone done work on this topic)? Systems/technology to monitor energy exists and are tested. The level of energy usage was gained. Hilti JAIBOT. Robotization of brick-laying is demonstrated in LTU but they identified that lack of drawing information (digital) to feed the robot was a problem. Using robotics for specific activities, eg drilling. Automated production in wood housing industry. Different centras; Linköping, Mälardalens högskola, KTH, LTH Suppliers doing prefab sometimes using robots/automation. Robotic dog that scan the construction site, and built up a model as-built at that time. Assembly of boards has been done by robots.	What's IN: Increase quality. Quality of datainput to robots. Monitoring energy?. Business models. Optimized productivity. Adaption of existing solutions to harsh environment at construction site. New design processes. What's OUT: Existing types of logistic planning,,Skanska, LiU Traditional forms of project management, leadership etc,,NCC, LiU Current way of organizing the contractor comapnies (project-based). Does not facilitate for change! Detachment of HQ and autonomous projects,,LiU Scope: What's out?	Solutions demonstrated on 5 projects. Zero accidents. Reduce the work environment risk on the construction site by using robotics for risk work. Safer building sites. Integrated planning for construction and manufacturing Ergonomics have improved significantly. Integrated planning for construction and manufacturing and its information is fed into the robots and they can build the building with little energy usage. Site management becomes controlers/monitors of the site progress. Contractors will source the robots from different contech companies.

What Drivers does this respond to?		**What are the links to ideas in the How layers?**	
Data protocols, standards and management. Supply chain development and productivity. New digital focussed Competitors. New collaborations change the industry. Safer working enforced by legislation. Reduced CO2 emissions and sustainability.			Cloud services to enable real-time visualisation and editing of data, also access via mobile devices. Sensors and tagging (where are materials and tools). Integrated planning for construction and manufacturing. Robotics in complex tasks. Prefabrication on construction site for selected parts Collaboration between construction companies & supplier & tech companies and Unions. Data collection to plan and control (AI). Data collection to plan and control (AI). Develop tools to make to connect model, quantities, location planning and cost in an easy way to use. The BIM model is the governing document. At the top of the hierarchy.

	Short term 2022 - 2025	Medium term 2026 - 2030	Long term 2022 - 2040
Please describe development path towards the desired future. What are the key milestones?	Create partnerships with robotic companies so they can develop wht we Pilot projects in cooperation with robotics developers 1. Identify information (e.g. length, quantity, etc) that need to be digitalized 2. Identify what systems need to be connected to exchange information. 3. Build API to exchange information from systems Early collaboration between construction companies, supplier and developer Hire people with experience of automation/robots The BIM model need to be the governing document. At the top of the hierarchy Pilot projects. Which need to be evaluated Select operations that can be done by robots	Ensure infrastructureon-site to be able to use robots. E.g. enough capacity in the power grid, An interface making robot programming easier	Industry transforms from no-tech to high-tech, World class productivity Productivity, work safety improvements Higher productivity, shorter construction times, safer construction sites and
How will the project be: created; lead; what collaborations; are needed?	Create seed money for start-ups	Start-ups use seed money with focus on dvelopment, Research program adding support to start-ups, both tech and busines support Advanced technology attracts the younger generation and other skills to the	Previous work has created confidence in robots, i.e. management adds
How competences and resources be developed?	Learn from car industry Identify what competences exist in-house and what competences are Exchange of experience and skills between different industries. Collaborati	Collaborate with suppliers using automation in thier production	
How will the legal or commercial, or stakeholders aspects be addressed? (if required)	BIM-model is basis for contract The BIM model is the governing document. At the top of the hierarchy Agreement for IP to be used		

4.6 Connectivity and Data Standards

Table 27 - Topic roadmap - connectivity and Data Standards

Topic: Connectivity and agreed data standards for data flows between construction process and IT Systems		Initial scope: Easy set up of cost competitive connectivity across a site in which multiple suppliers and connected devices can quickly establish.	Participants: Horestrand, Martin / Tofalvi, Ina / Bergsten, Anna / Synnes, Kare / Wikstrom, Karin
Please specify, if possible, What is required and any targets (if possible) for this solution	**Short term** Connectivity that has enough capacity to be shared between all parties on a site combined with an effective cost sharing mechanism Open platforms/suppliers = easier connection of construction sites to get started identify our common ground and set common standards Connectivity that has enough capacity to be shared between all parties on a site combined with an effective cost sharing mechanism Connectivity that has enough capacity to be shared between all parties on a site combined with an effective cost sharing mechanism Open networks that work in the environment where we build	**Medium term** Seamless common standards	**Long term** Automatic unlimited network access no matter where your project is located and the type of equipment used
Description/scope of the solution and its potential applications?	**What lessons learned will be applied?:** Standards and platforms must enable connected work sites Consider how Sustainability and the Environment can be enabled by digital Safety should be a key focus of developments Seek Productivity improvements Benefits need to captured and demonstrated to gain impetus in the industry **Where are we now ?** Pilot projects are being evaluated We have some connected workplaces The construction environment poses challenges for connection	**Scope** What's IN: Building the knowledge to use the connectivity any wireless connectivity on a construction site connectivity infrastructure Open for all to use without payment to use (but costs need to be shared) How companies will set up and access Scope: what's in? What's OUT: Brand new standards	**Desired future (vision):** Universal system that is easy to connect to and handles the cost of it Several suppliers of the system build to a universal access (e.g. not dominated by proprietary system) It must enable real-time data transmission (demands will increase)
What Drivers does this respond to?	Sweden Industry competitiveness (and flexibility) Supply chain development and productivity Data protocols, standards and management New collaborations change the industry Low profitability in the construction industry (low margins resulting to little innovation) Digital capability improves quality and product performance Safer working enforced by legislation Reduced CO2 emissions and sustainability	What are the links to ideas in the How layers?	Affordable and reliable connectivity solutions on main parts of 99 % of the sites Digital twins of the construction site Open standards agreed by sector Collaboration between construction companies & supplier & tech companies and Unions Productivity connectivity 'in a box' for easy connection of construction sites Inc. business model Drones for measurements Track and trace Integrated planning for construction and manufacturing

Please describe development path towards the desired future. What are the key milestones?	Short term 2022 - 2025	Medium term 2026 - 2030	Long term 2022 - 2040
Technology and standards	Create a mechanism to share current and future experience across the major companies Build collaboration with Tech companies on standards Setting requirements on a Industry scale to align the supply chains and equipment manufacturers Engage clients to support the universal connectivity of data (legacy for the	Develop plug and Play connectivity for a site and Pilot the system Industry agreement to roll out the system User cases	
Operation	Establish the options business model Who owns data / design/ construction / maintenance phases Establish the Ground rules e.g. use BIM, legal terms etc	Establish the basis for commercial arrangements (assigning the agreements) Determine how the network will be sustained	
People and management	Establish digital process managers to build implementation Share and gain support for the concept with Industry and clients	Build knowledge - how to do it, the training needed and the benefits	
How will the project be: created; lead; what collaborations; are needed?	Build a network committee for sharing cooperation between Skanska/NCC/PEAB Lobby government to support this initiative		
How competences and resources be developed?	Change in education for future white/blue collars Provide the on site personnel with digital support	Lifelong learning courses and training	
How will the legal or commercial, or stakeholders aspects be addressed? (if required)	Make sure data aspect is included as a natural part of the business agreement between entrepreneur and customer		
Other enablers, barriers and key risks?	Risk of sub optimising cost and benefits by projects or organisation Municipality need to follow industry agreement Risk; too expensive processes = smaller companies wont be able to join		

4.7 Consolidated Topic Roadmaps

Table 28 - Consolidated Topic Roadmaps

Topic Roadmap combined view			ST (2022 - 2026)	MT (2026 - 2030)	LT (2031 - 2040)
Trends and Drivers	External drivers	Political, Social, Technology, Legal, Economy, Environment and Safety	Safe working enforced by legislation		
			Government push for Digitalisation		
			More and affordable housing / buildings	Circular economy (Waste and Water) recyling / reuse re-process	
			Remote working capability (e.g. covid)	Copyright - Legal terms eg. a model	
				New bank initiative will increase focus on sustainability and efficient work sites to get favorable bank terms	
				Lack of construction site workers	
		Competition e.g. International	Increased competition from International construction companies e.g. China etc		
				New digital focussed Competitors	
	Value chain Perspectives	Customers (e.g. owners, clients etc..)	Reduced CO2 emissions and sustainability		
			Customer and new generation employees create demand for the use of digital technology (and for later use) e.g. digital twins		
			Customers requiring project and cost transparency		
		Tech Companies	Utilisation of technology development		
			Availability of (also advanced) technology and expectations to be able to use it..		
			Data protocols, standards and management		
			Development of Technology companies focussed on construction		
		Research and Development	Ability to create a good Ideation/ mass collaboration culture/ "fail-fast" approach		
			Data capture enables more Research for construction industry		
		Construction Co / main sub-contractors		Digital capability improves quailty and product performance	
			Increasing data use for management		
			Sweden Industry competitiveness (and flexibility)		
			Construction leadership for digital adoption		
		Resource suppliers (e.g. materials, people, systems etc.)	Supply chain development and productivity		
			Suppliers and their deliveries become Net Zero		
		Other	Attract talent to the Industry		New collaborations change the industry
			Low profitablity in the construction industry (low margins resulting to little innovation)		
			Changing work force		
Solutions (What)	Products	Production automation e.g. Robotics etc.	5. Robotic and Automation Pilots		
		Planning and control of production (inc quality & safety)	6. Connectivity and agreed data standards for data flows between construction process and IT Systems		
		Industry wide modelling commonality	2. Model based construction using 3 D as the legal document		
		Measurement and control systems (collection of data)	1. Common industry standard and regulations for information and deliveries		
			4. Common / Joint /Open Platforms		
		Site operations configuration (APD situation layout) and planning		3. A true digital twin of both product and site	
Technology and Resources	Innovation & Technology	Connectivity	Track and trace		Affordable and reliable connectivity solutions on mainparts of 99 % of the sites
		Materials & components	Sensors and tagging (where are materials and tools)		
		Design tools and modelling	Digital twins of the construction site		
			Develop tools to make to connect model, quantities, location planning and cost in an easy way to use		
				BIM and Digital Twins	
					Integrated planning for construction and manufacturing
		Manufacturing processes		Prefabrication on construction site for selected parts	
		Construction & site processes	Data collection to plan and control (AI)		
			No paper processes/Trusted decisions		
		AI, Big Data & IoT (inc. devises, software etc.)	Cloud services to enable real-time visualisation and editing of data, also access via mobile devices	Develop smart algorithms to support operational decisions based on sensor data	Robotics in complex tasks
	Enablers	Standards & Regulation	Open standards agreed by sector		Open access APIs and standards between planning systems and organisations
			Establish legal and regulations on data ownership		
		Capabilities (inc. digital) / skills (inc. education) inc	Common standards and regulations for digital solutions		
		Partnerships & Collaboration / Unions	Collaboration between construction companies & supplier & tech companies and Unions		
			Business model		

The landscape above is the summation of the Topic Roadmaps and their linkages:

Data standards are proposed as enablers and should be refined in line with the latest digital development, achieved through joint commitment across the industry in the supply chain. Data ownership. The development path involves build trust leadership and coordination authority followed by analysing the current state of the art and piloting. Possible risks include competing for international standards.

Standardisation, ownership, collaboration, and digital solutions were vital to consider while developing model-based construction using 3D as the legal document. The potential scope of such development includes productivity improvement, application of digital twins and enabling digital supply chain. The development path involves leadership development, standards/regulations, interdisciplinary knowledge, e.g., behavioural knowledge, and new business strategies. **An effective data governance and IP could address potential risks posed by distributed leadership, technology change and a large users base.**

The key focus to develop a solution was **using digital twins demonstrators to achieve safety and environmental performances**. Transparency and real-time monitoring of safety and environmental concerns are crucial, involving demonstrators on safety, emissions, and materials. The key focus was on construction site and data value through model-based planning and collaboration. The development path of digital twins demonstrator involves forming data methodology, scaling up demonstrators, and ultimately the commercialisation of digital twins. Digital twin solution can benefit from research, creating value proposition and clarity on data ownership.

Common / Joint /Open Platforms requires agreed technology protocols and common standards. The development trajectory involves a mix of closed and open systems leading to platform development with unique contractual arrangement for data sharing. **New business models** and building trust will address the challenge of fragmentation of digital approaches and platforms**. Competencies around common business process and change of mindset require collaboration and consensus on common requirements. The path involves information on data, piloting, migration to 3D and defining value streams. Connectivity across the supply chain, environmental legislation and related government policies can support implementation.**

Robotic and Automation Pilots are essential to developing demonstrators that eliminate repetitive/time consuming/safety risk jobs. Leaning, need analysis and collaboration are key starters to achieving long-term targets, including deployment of Robots, and establishing seamless data and processes. Start-ups are essential in venturing into robotics. There are various initiatives at the present on which Robotic pilots can take advantage. Inspiration can be achieved by attaining optimised productivity, improving quality, and making building process safer. Short term development path involving talent, need analysis and creating partnerships to ensuring infrastructure compatibility and longer-term establishment of Higher productivity, **shorter construction times, safer construction sites and "cheaper" buildings for the clients. The development can be enabled by creating seed money for start-ups, knowledge exchange, reducing barriers for collaborations and creating value proposition** for investment risk aversion.

Connectivity and agreed data standards for data flows between construction process and IT Systems requires the development of seamless standards, infrastructure capacity and availability of open networks. Small scale piloting is the best starting point towards attaining universal systems in the longer term for connectivity involving real-time data transmission, accessibility, and affordability. The development path is categorised under talent, technology standards and business models. Networking, collaborations, and public sector involvement were suggested towards the development of connectivity. Life-long learning is an essential part of the development trajectory alongside ensuring data is included in agreements involving businesses. Such agreements with the involvement of local public sector organisations help in mitigating risks linked to optimising costs

4.8 High Level Summary

For the purposes of illustration, the following Roadmap has been focussed on the core content and so that it can be translated into a high-level landscape that can demonstrated via presentation.

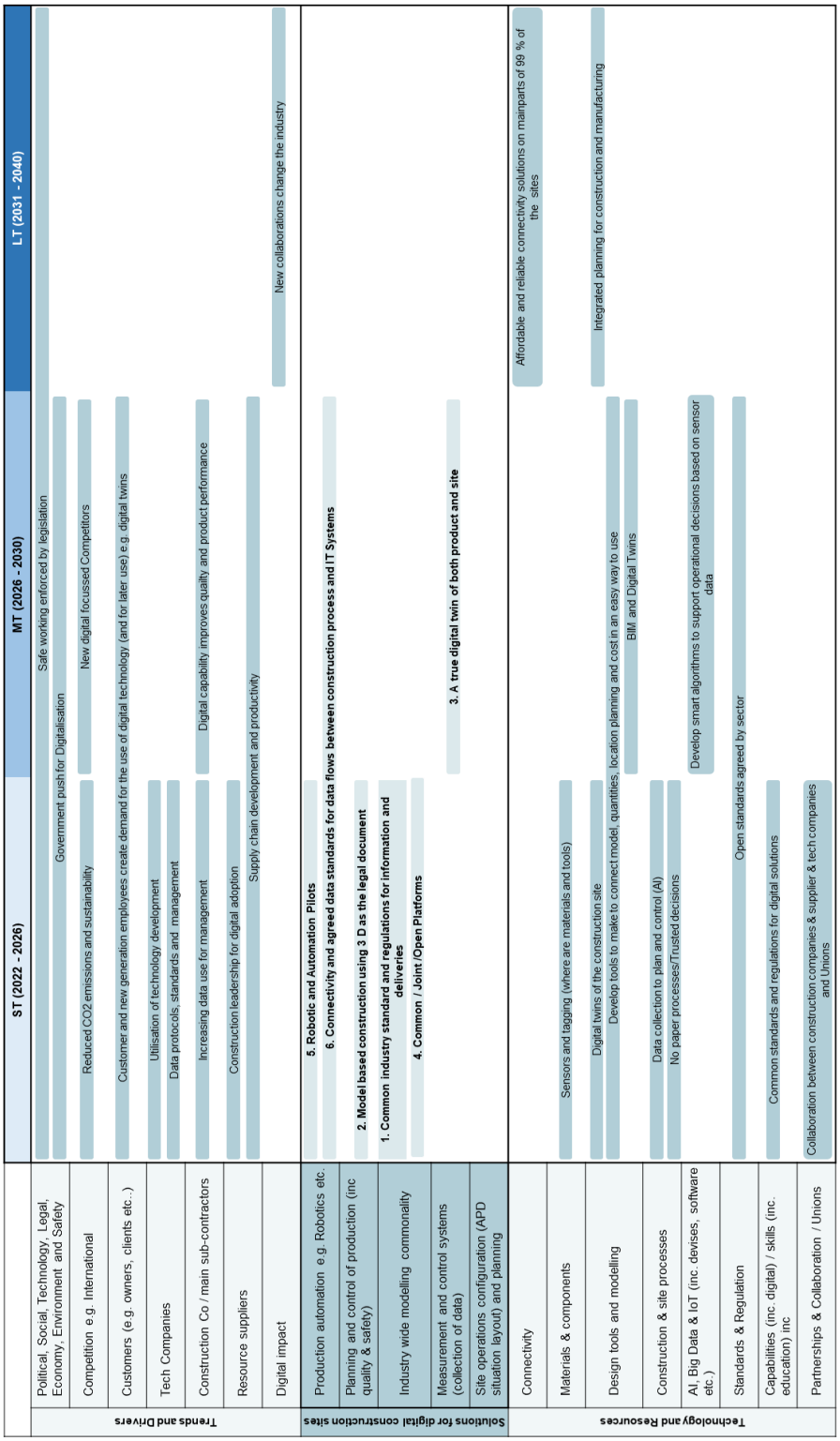


Table 29 - High-level Strategic Landscape

5. Conclusions and next steps

Previous knowledge is captured during the **Lesson learnt** phase related to digital initiatives/studies in the construction domain. There were three messages: 1) Use data and trust it, 2) The benefits case must be clear to attract digital investments and 3) There needs to be network access and standards that work for the industry. These themes are carried forward and link to the Topic Roadmaps.

The revisions to the scope ensured that focus was developed on the needs of the construction industry in the expectation that technology is the how. The personas session did illustrate what life might be like in support of this approach, however, the Vision continued to be more centred on the technology. There may have been several reasons for this. 1) In the context of the Federation the focus is on what will enable the industry 2) Innovations is a topic for individual businesses. 3) There was a focus on the common and shared need to build a basis of collaboration across the Industry that is inclusive of all e.g., the supply chain. All of the perspectives did significantly link to people, environment, and cooperation.

Taking inspiration from lessons learned and vision, **trends, drivers, and challenges** were identified in short, medium, and long terms, primarily focusing on external and value chain perspectives highlighting the importance of Industry productivity, sustainability, and supply chains. The most significant factor was the expectations of customers who are demanding faster change ahead of other influences e.g. legislation.

The prioritised solutions focussed on mobilising the industry for a digital future and ensuring network access and the flow of data, from material data sheets to any material supply flow and stocks becomes a possibility through **open platforms, connectivity, and standards. This should allow for inclusion across the industry rather than restrictive or proprietary systems that increase costs and reduce productivity.** Safety and the Environment are also key areas which would benefit from information flow, and they are also the common ground upon which projects and demonstrators can be established especially as the industry wants to make progress on these key topics.

There were many considerations given to **Technology and resources** to enable the digital developments and they can be seen in the categories of collaborations, broader network strategy, product and process development, and policy/standards. **The challenge remains about how to get started, the role of government and bodies such as the SBUF can help. In this respect building commitment at Board level in the larger organisations, linking this to the research agenda and Government policies/funding will be key.** There is a need to address the dichotomy identified in lessons learned – the benefits must be proven vs. the recommendations to develop open networks etc so enabling digital developments. The SBUF could have a significant role to play in addressing this issue.

The next stage in how the industry should meet the challenges of digital construction sites is represented by the key topics selected by the design team, with cognisance of the delegate voting. They demonstrate the opportunity for cross-industry developments to raise the competitiveness and productivity of the industry:

- Developing common data standards/regulations
- Model-based construction using 3 D as the legal document
- Use of digital twins demonstrators
- Common / Joint /Open Platforms
- Robotic and Automation Pilots
- Connectivity and agreed data standards for data flows between construction process and IT Systems

The topic roadmaps give an actionable start and recommendation to the SBUF, Installatörsföretagen and the leading Construction business for the development of digitally connected work sites in Sweden.

The core members of the project team:
Joakim Jeppsson (Project leader) - joakim.jeppsson@skanska.se
Colin Haden (Lead facilitator) – IfM Engage cdh35@cam.ac.uk
Dr Arsalan Ghani – IfM Engage aag35@cam.ac.uk
Andi Jones – IfM Engage ajj48@cam.ac.uk
Industrial Associates, IfM Engage

Appendices

A. List of data files
B. List of contributors
C: Lessons Learned
D1: Vision
D2: Vision Personas
E1: Landscape – trends, drivers, and challenges
E2: Trends and Drivers - Voting by Group
F: Solutions (details)
G: How layer information
H: Linkage Grids
I: Feedback
J: Roadmapping

A: List of data files

Facilitation slides	Planning, invites & feedback	Prework & Pre-read	Report	Roadmaps	Workshop Miro Boards
1. Steerco meeting - Project commencement.pptx	Actual Attendance+Timeline.xlsx	Prework submissions 1	Editable copies of Report pictures.pptx	Connected construction Landscape (210521).xlsm	Topic Roadmap.pdf
2. Steerco meeting - Recruitment&Responsibilities.pptx	Completed Feedback - Connected Construction Sites .xlsx	Prework submissions 2	Editable landscape.xlsx	Connected construction Landscape (280521) summary.xlsm	2 -Topic Roadmap.pdf
3. Steerco meeting - Recruitment&Responsibilities update.pptx	Email.docx	Pre-read for Topic Roadmaps.xlsx	IfM Engage Report for SBUF280521.docx	Connected construction Landscape (Topics) Image.xlsm	3 -Topic Roadmap.pdf
4. Steerco Prep for Why and Vision.pptx	Info to Support invitations.pptx	Pre-read for Vision and Why .xlsx		Connected Construction Topic Roadmaps summary (210521).xlsm	4 - Topic Roadmap.pdf
5. Steerco review Preparation for What.pptx	Invitations and timings - Connected Worksite Roadmap.xlsx	Prework 1 request.xlsx		How - Analysis and Summary.xlsx	5 - Topic Roadmap.pdf
6. Steerco meeting - Prioritisation context.pptx	Invites email.docx	Prework request 2 and info for What and How workshop.xlsx		Lessons Learned - Analysis and Summary.xlsx	6 - Topic Roadmap.pdf
7. Steerco Topics for Roadmapping.pptx	Kick off meeting slides for delegates.pdf			playback.m3u	Connected Worksites Vision Why - Master - Analysis of clusters.pdf
7b. Topic Roadmapping Template (options).pptx	Kick-off invitation letter.docx			Topic A roadmaps.mp4	Group A - How.pdf
				Topic Roadmap reports.xlsx	Group A - Lessons Learned.pdf
a. Facilitation Kick-off Webinar.pptx				Vision - Analysis and Summary.xlsx	Group A - Vision.pdf
b. Facilitation-LessonsLearned.pptx				What - Analysis and Summary.xlsx	Group A - What.pdf
c. Facilitation-Vision and Why.pptx				Why - Analysis and Summary.xlsx	Group A - Why.pdf
d. Facilitation-What and How .pptx					Group B - How.pdf
e. Faciliation-TopicRoadmapping.pptx					Group B - Lessons Learned.pdf
					Group B - Vision.pdf
					Group B - What.pdf
					Group B - Why .pdf
					Group C - How.pdf
					Group C - Lessons Learned.pdf
					Group C - Vison Group.pdf
					Group C - What.pdf
					Group C - Why.pdf
					Group D - How.pdf
					Group D - Lessons Learned.pdf
					Group D - Vision.pdf
					Group D - What.pdf
					Group D - Why.pdf
					How layer - Prework Inputs.pdf
					Miro Overview of What and How.png
					Miro Vision Overview.png
					What layer - Prework inputs.pdf
					Why layer top 10 drivers, trends and challenges.pdf

B: List of Contributors

Organisation type	Affiliation	Delegate
Construction	Lindbäcks	Anna Bergsten
	NCC	Karin Wikström
	NCC	Håkan Wedsberg
	NCC	Sandra Lasson
	NCC	Kajsa Simu
	PEAB	Max Bergström
	PEAB	Henric Jonsson
	Research	Claes Henschel
	Skanska	Joakim Jeppsson
	Skanska	Ronny Wahlström
	Skanska	Peter Samuelsson
	Skanska	Mats Dunmar
	Skanska	Martin Hörestrand
	Skanska	Lotta Wibeck
	VRA	Andreas Udd
	VRA	Fredrik Nordqvist
Research	Aalto U	Olli Seppänen
	LiU	Martin Rudberg
	LiU	Micael Thunberg
	LTU	Lars Stehn
	LTU	Jan Byfors
	LTU	Kåre Synnes
	Luleå University	Olle Samuelsson
Resource suppliers	Alimak Group	Charlotte Brogren
	Cementa	Robert Larsson
	Hilti	Johan Leufstedt
	Lambertsson	Jimmie Holst
	Ramirent	Jimmy Dahlström
	Sain Gobain	NIkolas Hvid
	Södra building systems	Henrik Blomberg
Tech companies	Autodesk	Oliver Lepinoy
	Avantech	Per Storm
	IT Consultant	Patrik Johansson
	Blue Beam	Christian Gren
	EquipmentLoop	Simon Fogbring
	Ericsson	Sebastian Elmgren
	Microsoft Construction Vertical	Micael Larsson
	MyLoc Construction Logistics	Magnus Rydberg
	Qlocx	Björn Nyckelgård
	TPO Onsite Conectivity (Cisco/Tele2)	Hampus Rosenqvist
	Zynka BIM	Ina Tofalvi

C: Lessons Learned

Rank	Summarised findings	Outputs from the sub groups		
1	**Seek Productivity improvements**	Productivity has not increased as a result of past digitalisation projects - this continues to be a challenge - however product quality has increased Productivity improvements are harder to demonstrate	Gaining productivity is significantly important in connected worksites. The digital platforms should enable productivity as it has cost implications	**Productivity:** 1. Inefficiencies due to Covid are bringing the spotlight on the need to increase productivity and maintain prices 2. Affordable living in the future 3. Assists younger people to live in big cities
		Information management: 1. Smart use of data will bring benefits in productivity and therefore a better economy 2. Contractual management of data - how to use this for the greater / shared good 3. Access control of data (e.g. token based access or role based access..) 4. Control Room idea to collate all information in one area - remote information management	Collaborations with ecosystem actors in AI. Increased productivity and environmental sustainable	Change management - change the culture. Focus on this and productivity will follow
2	**Safety should be a key focus of developments**	Safety should be the key focus in operations enabled through effective communication	Collaboration means, productivity, safety and sustainability - consider in the business system	Workplace safety has been a significant driver for moving to digital solutions - penalties from government
3	**Consider how Sustainability and the Environment can be enabled by digital**	Clients & government are moving towards sustainability - when clients require it the contractors do it	Customers are demanding environmentally sustainable business. This can be achieved by addressing CO2 emissions in the whole value chain	Collaborations with ecosystem actors in AI. Increased productivity and environmental sustainable
4	**Standards and platforms must enable connected work sites**	**Platforms and data:** 1. Big data analysis - a lot of interesting stuff but too many decision are still made on gut feeling 2. Flexibility to achieve with more open systems (too much built in complexity) 3. Transparency and safe data 4. Collect and leverage existing data is now possible	Robust infrastructure should be underpinned by a single IP communication layer. Digital capabilities can be built on top of this For the enablers platforms & data, WiFi6/5G, One IP Communication Layer and digital capabilities - collaboration between different organisations is required	
		Standards act as barriers, particularly when there are too many. This is the case with digital standards as well.	**Information management:** 1. Smart use of data will bring benefits in productivity and therefore a better economy 2. Contractual management of data - how to use this for the greater / shared good 3. Access control of data (e.g. token based access or role based access..) 4. Control Room idea to collate all information in one area - remote information management	
5	**Focus on turning data into value and insight**	**Platforms and data:** 1. Big data analysis - a lot of interesting stuff but too many decision are still made on gut feeling 2. Flexibility to achieve with more open systems (too much built in complexity) 3. Transparency and safe data 4. Collect and leverage existing data is now possible	Data management is key to join up and integrate	Data ownership and sharing
		Platforms and data: 1. Big data analysis - a **lot of interesting stuff but too many decision are still made on gut feeling 2. Flexibility to achieve with more open systems (too much built in complexity) 3. Transparency and safe data** 4. Collect and leverage existing data is now possible	**Digital maturity:** 1. Individual teams may be mature (learning done at individual not company level) but companies are not 2. Biggest issue is with small scale supplier (5 - 10 person) 3. Lack of ability to trust the data 4. Transparency is seen as a risk	Lack of planning and Project management
6	**Enable developments to include all business sizes and the supporting supply chain.**	Integration of the Supply chain	**Digital maturity:** 1. Individual teams may be mature (learning done at individual not company level) but companies are not 2. Biggest issue is with small scale supplier (5 - 10 person) 3. Lack of ability to trust the data 4. Transparency is seen as a risk	
7	**New business models are needed for development and collaboration**	Business models that support collaboration and mutual benefit	Scaling up digital technologies also act as barrier to normal business operations	Connected construction sites project succeeded partially due to research funding availability. Increased research funding in this industry is key A new internal business model to include development is needed
8	**Developing construction industry businesses and people with digital skills and capability**	Leadership needs to promote collective learning to drive change forwards Re-skilling people as things change is important	Attractive job opportunities need to be created for younger people/ new talent. Staying relevant is important	**Digital maturity:** 1. Individual teams may be mature (learning done at individual not company level) but companies are not 2. Biggest issue is with small scale supplier (5 - 10 person) 3. Lack of ability to trust the data 4. Transparency is seen as a risk
9	**Benefits need to be captured and demonstrated to gain impetus in the industry**	Validation and benefit capture to show value of going further	**Digital scale up:** 1. Construction is product based and therefore ROI is based on each product (not several products) 2. Project economy - very difficult to scale at a company level 3. Digital is seen as an overhead cost 4, Ability to show evidence - is this really worth it or is it such as hype	
		Both strategy and tactics are required to address shortcoming and gaps on digital maturity of companies within the whole value chain. Talent is important in this scenario.	Connected construction sites project succeeded partially due to research funding availability. Increased research funding in this industry is key A new internal business model to include development is needed	
10	**Funding Research is vital for developments**	Connected construction sites project succeeded partially due to research funding availability. Increased research funding in this industry is key A new internal business model to include development is needed		

(The blue text highlights the portion of the comment relevant to the learning point)

D1: Vision

What is the likely Industry and Business perspective? (in 2031 +)	Systems are integrated	Automated material flows	We take care of the environment	New business models have changed the way we work	We manufacture much more content off-site
	Systems are integrated across the industry and the whole supply chain *and automated*/JiT	Material - flow and production management is guided by digital information system	Environmental consciousness drives supply chain decisions	New Business models within the industry	High levels of off-site manufacturing
	14	9	7	2	2
What development will have been done to support the vision?	Robust data standards across the industry	Visibility across projects and the supply chain	Sensors widely used	Policies support the Industry	
	Collaboration is enabled by common standards across the Industry *& Robust data strategy*	Visibility enables management across all constructions projects & Resolving the complexities in construction sites of Multiple Suppliers	Sensors on everything for asset control to performance	Government policies proactively support productivity and growth	
	15	6	3	2	
What skills, capabilities and resources will be in use?	An information Ecosystem is established across the Industry	Culture to use digital	Technology makes it a great place to work		
	Information capability using connected sensors for asset control and performance & Information Ecosystems system are utilised & Seamless communication across construction ecosystem	A culture for utilising digital information for advantage *& All layers of management are digital capable*	It is an attractive industry to join / Technology enhances workers skills and capabilities		
	17	7	7		

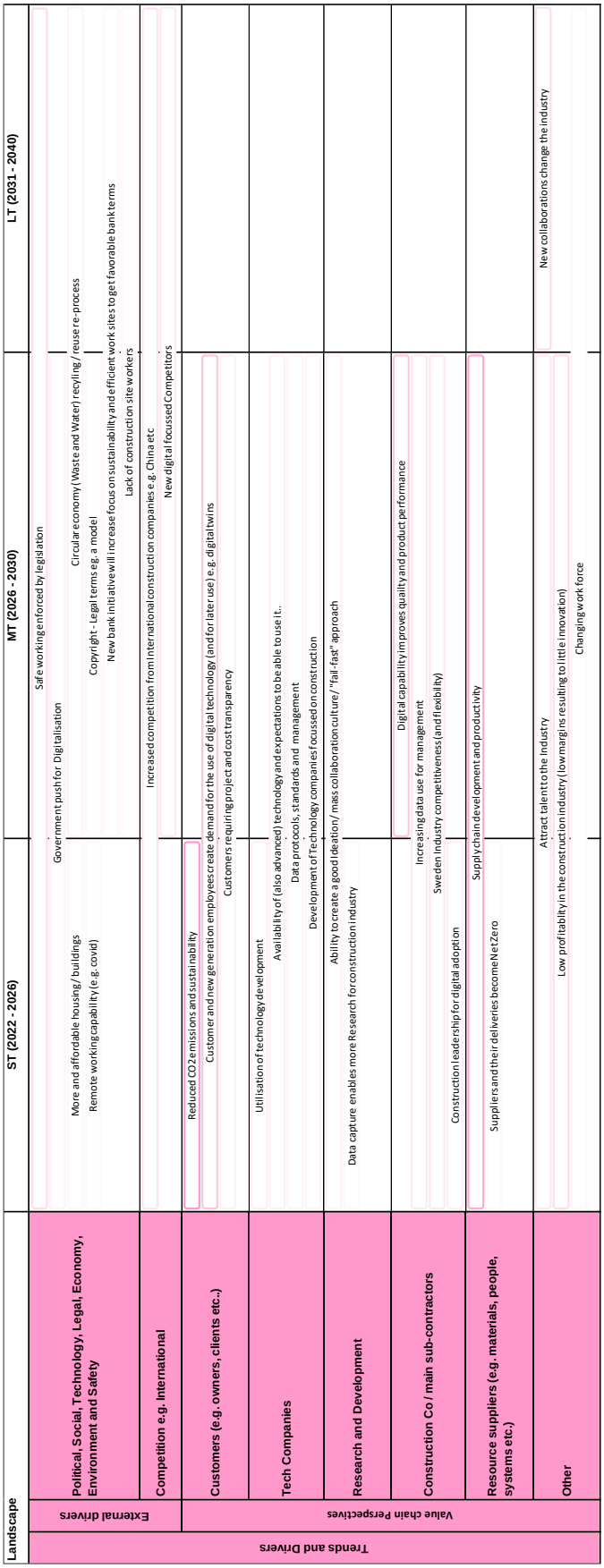
The consolidated view and dot vote scores across the four subgroups

D2: Vision for Personas

On a construction site, after 2030+, what will it be like for:

Construction Group		Researchers Group		Technology Group		Resource Supplier Group	
Area Manager or Business Unit Head		**A construction worker**		**Project manager**		**Sub-Contractor or supplier to site**	
Summary of categories	*Post-its to bring the vision to life by imagining you are the Area Manager or Business Unit Head*	*Summary of categories*	*Add post-its to bring the vision to life by imagining you are a construction worker*	*Summary of categories*	*Add post-its to bring the vision to life by imagining you are a project manager*	*Summary of categories*	*Add post-its to bring the vision to life by imagining you a Sub-contractor or supplier to site*
Information at fingertips	Any information is only handled when you add value to the info otherwise, info is moved and presented automatically Online dashboard for all projects in his/hers business area used to optimize resources between the project Updated data to use in product optimization for coming projects Visual support for acting on-time data now able to predict more than react After everyday see what is produced and actual revenue Fully up-dated schedule of what is produced and what's cost affected to it on each project and all together.	**Great working environment**	A structured, safe, and clean working environment supported by digital tools.	**Efficient allocation of resources**	More efficient allocation of workforce and resources	**Collaboration across the supply chain**	Nose-to-tail circular innovation
Planning scenarios	Updated data from projects to used as a ground for decisions, bid, safety preventions etc Management steering platforms by Tencent, Baibu, Huawei and Xiaomi Build the project in a gaming environment to play the best solutions (planning, work descriptions etc)	**Recognised as a high status worker**	Construction workers are seen as high status work that attracts new skills and capabilities Multi-competent Calm, less stressful!	**Data driven**	Data driven decisions including suggestions PM able to sell/buy/trade data everyday (data is an asset, like workforce, raw material, building products)	**Project Integration across the supply chain**	Integrated in the project earlier, true Team member integrated in the project
Flexible working and a great place to work	Remote management team members are virtually on site through its avatar Easy to attract new talents to the business as employees can impact more on there daily work (and not risk to be injured) No problem to work 24-7, have vacation etc, for all workers on site. You can plan and do some work where ever you are no matter what role you have. As manager its easy to adjust the co-workers activities. All industries needs the same competences, can share and move between	**Planning considers the workers**	The digital twins (not just site, but full value chain) are true representations of the physical reality and can be used to support the workers. The managers are educated in digitalization and planning We are able to plan work, deliveries	**Proactive approach**	Proactive with less firefighting	**Use of Big Data across the supply chain**	Contributes to clients and own productivity based on data Be able to see live updated progress, article lists and stock balance on building site
Client meetings	Interactive hologram meeting with a possible client on the moon regarding the development of a neighbourhood in the future produced areas	**More outsourcing to specialists**	Some of the work done by contractor is outsourced to technology provider or some one else	**Leadership**	A thing I hadn´t the time to put in is that good projects also have the Site Manager being ON SITE to make the whole Team work a to the same goal of deliver the product in right time. Everyone will have a better workday.		
Safety and environmental	Very low impact on environment, re-use material etc. Celebrate yet another year with zero accidents/incidents	**We have digital tools for your work**	Supported by on-demand tailored (bespoke) digital tools The digital tools (tablets, Hololens, etc.) are as important as the traditional tools (hammer, etc.) Since all buildings are populated with sensors, I get location-based support wherever I am on the site with drawings, prep-work, plans/schedules, etc. that are automatically updated.	**Real and virtual presence on-site**	No need to be on-site every day. Use Virtual Reality to check progress, supervise, provide solutions etc. Use the PM in more value activities		
Off-site construction by new high tech businesses	Construction Huts (byggbod) are delivered by CN high-tech firms, SAIC, BYD, Chery	**We are self organising**	We have control over the work and flows Loosely organised We have more trust in each other as information is transparent				

E1: Landscape – trends, drivers, and challenges



E2: Trends and Drivers - Voting by Group

Categories	Research (A)	Technology (B)	Construction (C)	Technology (D)	No. groups who mentioned the cluster
Attracting Talent	1				1
Work force skills and capabilities	4		2		2
Management digitally capable	3	1			2
New business models	2	5			2
Government Policies				1	1
Data sharing through common standards	11	6	5	1	4
Legal frameworks support digital working	1		1		2
Research can use common data			1		1
Decision support tools		1	3	3	3
Drawings (Design to build)	1	1	1	1	4
Data used for product, quality, and site performance	9	7	2	3	4
Easy to use on sites				2	1
Wide connectivity	4	1	2		3
Sensors used for more data	8		3	3	3
Use of Robots	2		1		2
Proactive safety	3		3		2
Environmental Inclusion		1	2		2
Capture Innovation		2			1
Management though data visibility		2	6	2	3
On-site manufacture and assembly	1			1	2
Material and production flow automation	2	1	2		3
Off-site manufacturing				1	1
Dynamically change site layouts	3				1
Digitalised industry gets investment	2				1
Categories	16	11	14	10	

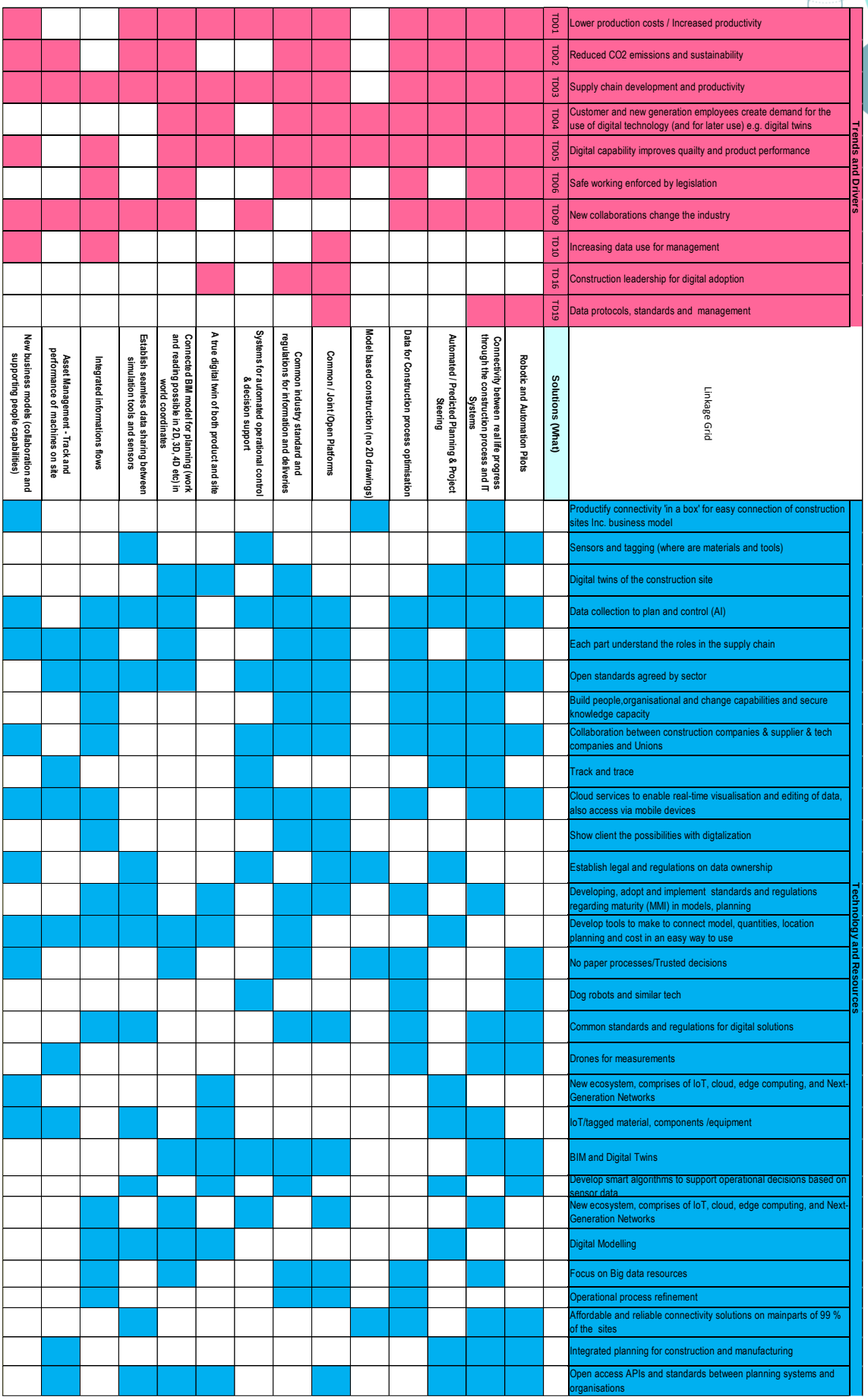
F: Solutions (details)

Technology and Resources	Time scale
Productify connectivity 'in a box' for easy connection of construction sites Inc. business model	ST
Sensors and tagging (where are materials and tools)	ST
Digital twins of the construction site	ST
Data collection to plan and control (AI)	ST
Each part understands the roles in the supply chain	ST
Open standards agreed by sector	ST-MT
Build people, organisational and change capabilities and secure knowledge capacity	MT-LT
Collaboration between construction companies & supplier & tech companies and Unions	ST
Track and trace	ST
Cloud services to enable real-time visualisation and editing of data, also access via mobile devices	ST
Show client the possibilities with digitalisation	ST
Establish legal and regulations on data ownership	ST-MT
Developing, adopt and implement standards and regulations regarding maturity (MMI) in models, planning	ST
Develop tools to make to connect model, quantities, location planning and cost in an easy way to use	ST-MT
No paper processes/Trusted decisions	ST
Dog robots and similar tech	ST
Common standards and regulations for digital solutions	ST
Drones for measurements	ST
New ecosystem, comprises of IoT, cloud, edge computing, and Next-Generation Networks	MT
IoT/tagged material, components /equipment	MT-LT
BIM and Digital Twins	MT-LT
Develop smart algorithms to support operational decisions based on sensor data	MT
New ecosystem, comprises of IoT, cloud, edge computing, and Next-Generation Networks	MT
Digital Modelling	MT-LT
Focus on Big data resources	MT
Operational process refinement	MT
Affordable and reliable connectivity solutions on main parts of 99 % of the sites	LT
Integrated planning for construction and manufacturing	LT
Open access APIs and standards between planning systems and organisations	LT

G: How layer information

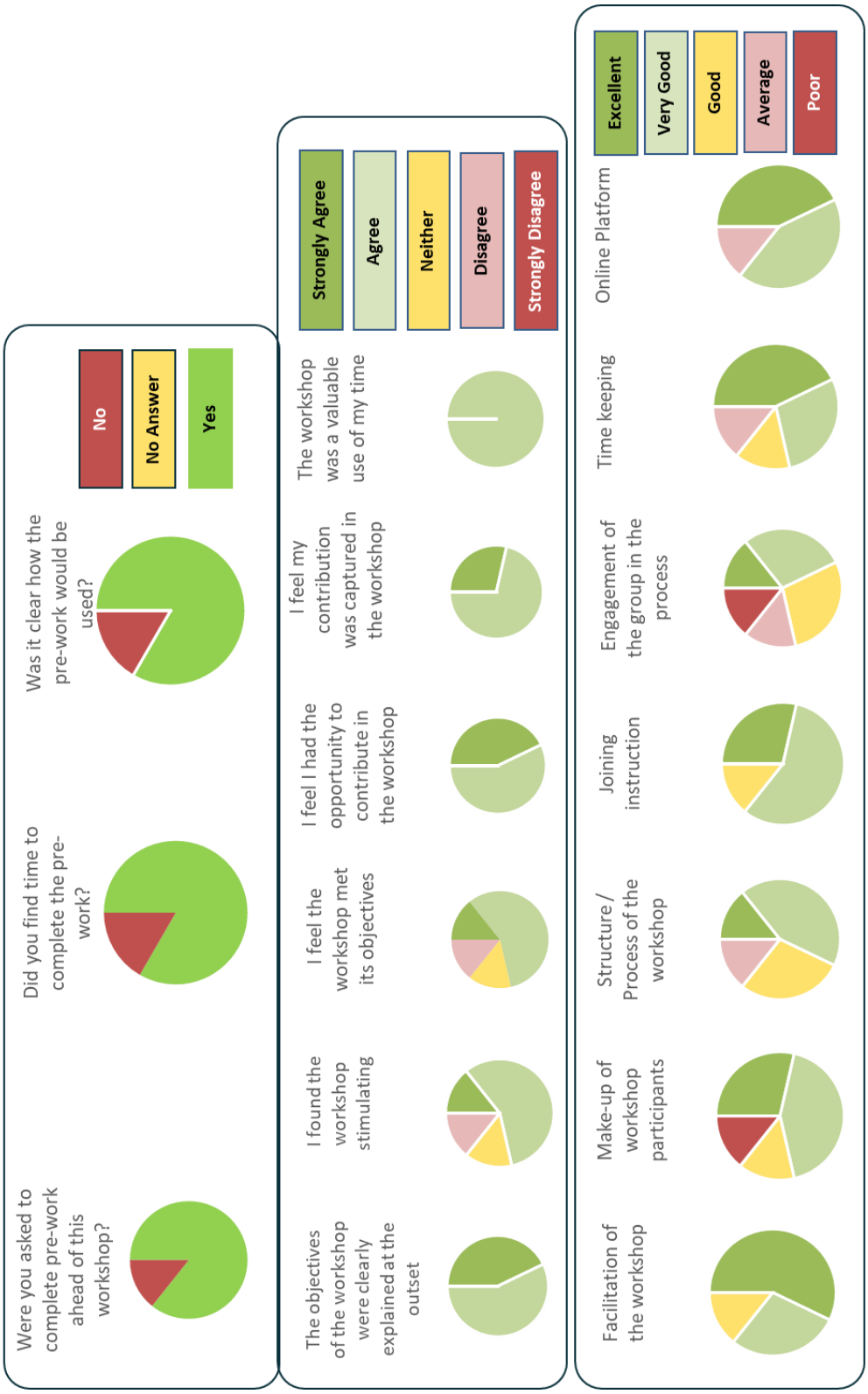
Title	Post-its
Robotic and Automation Pilots	Robotic and Automation Pilots - Robots do surveying works - Robots collect data (e.g. as built) - Pilot/demos for analysing pros and cons by robotics - Pilot projects with suppliers using high level of automation - Replace handcraft - Robotization on site (use 24/7), e.g. crane control, insertion of materials - Pilot testing
Connectivity between real life progress through the construction process and IT Systems	Connectivity between real life progress through the construction process and IT Systems - 3D design refined along constructions process - Connected Information - Connectivity between real life progress and IT Systems - Connection of model, quantities, location planning and cost - Need to digitally combine plan-, model- and progress data for real-time follow-up - 3D design with phase classification together with supplier at an early stage - Real-time field reporting (by connecting and tracking materials, equipment, and, most importantly, workers at the construction site) - Demonstrate an integrated method for planning and control of concrete operations incl. feedback to suppliers - Model, quantities, location planning and cost connected - Risk that the lead times of governing bodies reduce the possibility of early involvement with suppliers e.g. Designing safe solutions,
Automated / Predicted Planning & Project Steering	Automated / Predicted Planning & Project Steering - Total integrated planning, - Totally integrated planning - Self learning planning system based on AI, evaluate on KPI's connected to planning ability - Model, quantities, location planning and cost connected - Planning of concrete operations are updated in real-time, predictions of future state are based on latest sensor data, - Seamless integrated design, planning and production
Data for Construction process optimisation	Data for Construction process optimisation - Data is used to optimize the product and the production - Compare product and production data between different projects to optimization product and production predict the future in digital models (planning infrastructure, etc.) - Planning and control of concrete operations supported by smart algorithms are standard aiming to minimise time, cost, and CO2.
Model based construction (no 2D drawings)	Model based construction (no 2D drawings)
Common / Joint /Open Platforms	- Common / Joint /Open Platforms - Open, common databases/ technical platform with trusted ownership - Open platforms across Industry - Open Common databases for information (EPD, etc) to be used in the whole chain (A-F) - Data driven process - All solutions to be scalable and easy to set up for new projects and data to consumed on an aggregated level - open platforms for data collection
Common industry standard and regulations for information and deliveries	Common industry standard and regulations for information and deliveries
Systems for automated operational control & decision support	Systems for automated operational control & decision support - Control of indoor climate during production is data-driven. Feedback loop in real time to project and suppliers - Indoor climate is controlled by machines and sensors optimising energy use, CO2, and indoor quality
A true digital twin of both product and site	A true digital twin of both product and site
Connected BIM model for planning (work and reading possible in 2D, 3D, 4D etc) in world coordinates	Connected BIM model for planning (work and reading possible in 2D, 3D, 4D etc) in world coordinates - Support system for APD design based on AI
Establish seamless data sharing between simulation tools and sensors	Establish seamless data sharing between simulation tools and sensors - Systems talking to each other
Integrated information flows	Integrated information flows - Collect and use data
Asset Management - Track and performance of machines on site	Track and trace machines on site (for maintenance on machines performance, capacity...) - Automated planning and traceability for the supply chains - Track and trace (e.g. materials, machines)
New business models (collaboration and supporting people capabilities)	New business models

H: Linkage Grids



I: Feedback

Anonymous feedback was obtained from 7 respondents. The analysis and verbatim comments are available in the handover files.



J: Roadmapping

What is Roadmapping?

Roadmapping is a powerful strategic planning technique that is integral to creating and delivering strategy and innovation in many organisations. The graphical and collaborative nature of roadmaps enables strategic alignment and dialogue across functions. Extremely flexible, roadmapping provides clear direction and alignment of specific needs at all levels, including functional, organisation-wide, and even collaboration between organisations. IfM has helped more than 300 organisations with their strategic and technology innovation planning through roadmapping.

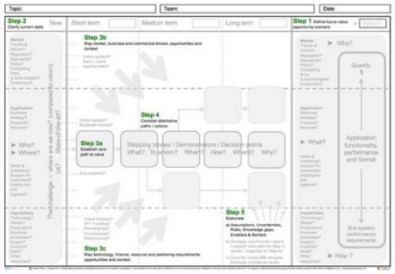
How can a Roadmap help an organisation?

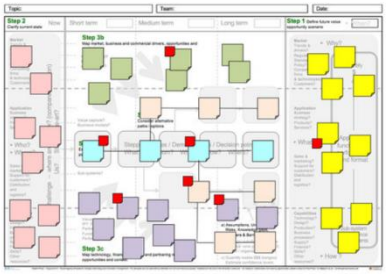
- Agile and iterative approach for strategy and planning.
- Flexible and adaptable to fit the needs of any business, organisation, or sector.
- The latest research combined with human expertise and thinking.
- Consensus-building approach to decision-making for key stakeholders to action workshop outputs.
- Visual outputs enable easy and effective communication of strategic intent.
- Alignment of commercial and technical strategy

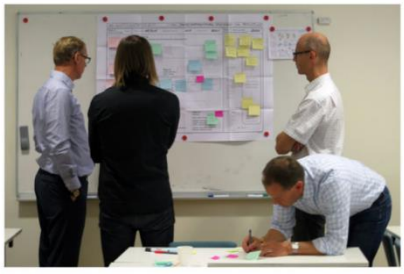
The S-Plan Process

Typically, workshops will involve between 15-25 participants (although more are possible with careful design and a team of facilitators). The S-Plan is usually carried out in a series of facilitated workshops and consists of four main steps:

Strategic landscape	Select value elements	Explore a topic	Agree a way forward
Consider the business as a whole and use the roadmap framework to capture information from all the process participants as well as the identification and prioritisation of value elements within the landscape.	Further explore areas such as innovation opportunities or strategic topics.	The roadmap framework is used in small groups to explore and define each value proposition (or innovation opportunity) in greater detail and map out how they can be achieved.	Topics are presented for discussion to identify and/or agree a way forward (e.g. regarding strategic actions emerging from the roadmaps).

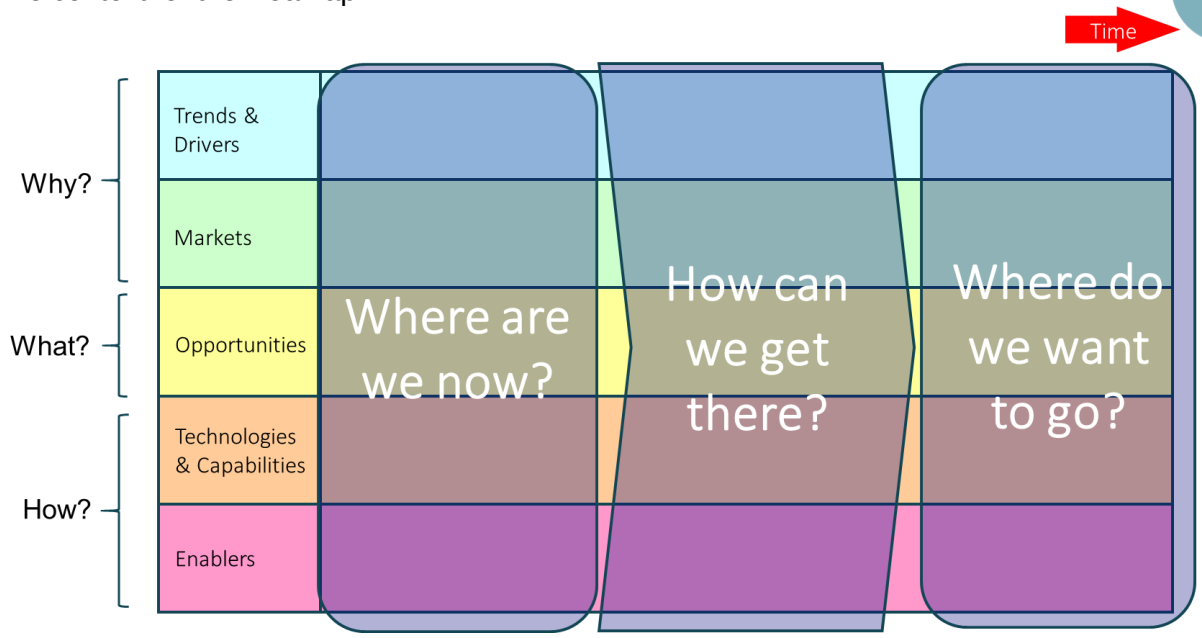




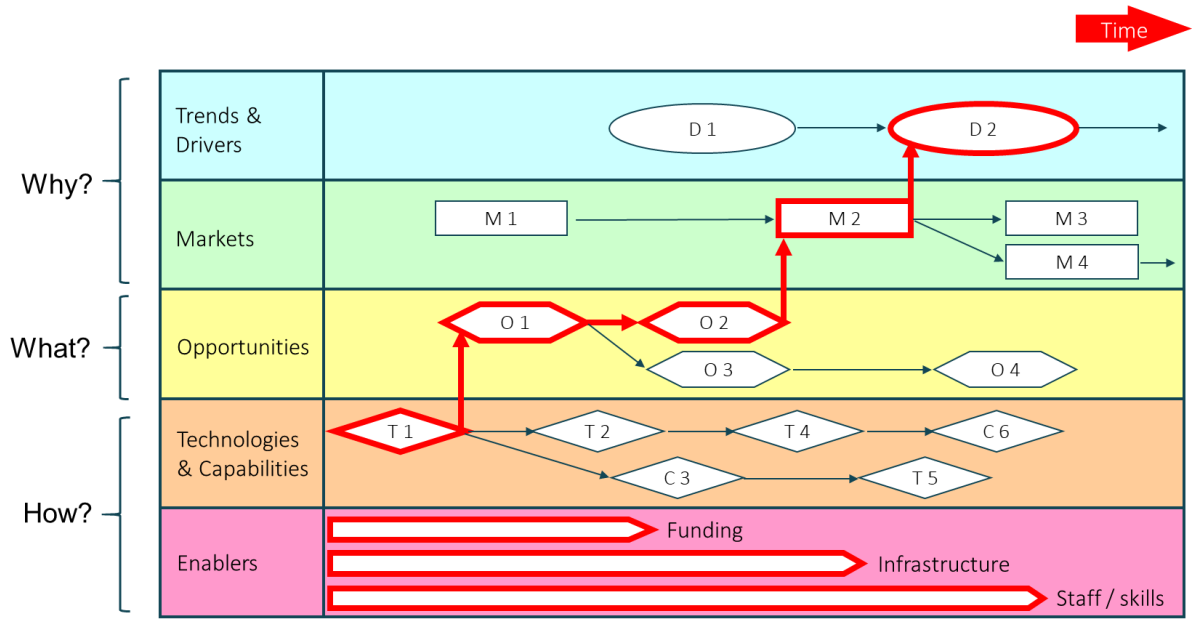


To know more see our Video clip: https://youtu.be/0JxsSHjyJPc

The context for the Roamap



How the Links between the layers of the Roadmap inform the decisions on timings



For more information about this report:

Contact: Colin Haden or Dr Arslan Ghani
E: cdh35@cam.ac.uk / aag35@cam.ac.uk
T: +44 7833 494940 / +44 7583 960675

Institute for Manufacturing: IfM

The IfM is part of the University of Cambridge's Department of Engineering. With a focus on manufacturing industries, the IfM creates, develops, and deploys new insights into management, technology, and policy. We strive to be the partner of choice for businesses and policymakers, as they enhance manufacturing processes, systems, and supply chains to deliver sustainable economic growth through productivity and innovation.

IfM Engage

IfM Engage is owned by the University of Cambridge.
It transfers to industry the new ideas and approaches developed by researchers at the IfM. Its profits are gifted to the University to fund future research activities.

IfM Engage, 17 Charles Babbage Road, Cambridge, CB3 0FS, UK
+44 (0)1223 766141 | ifm-enquiries@eng.cam.ac.uk | www.engage.ifm.eng.cam.ac.uk

UNIVERSITY OF CAMBRIDGE
Department of Engineering

IfM Engage