Asia-Pacific
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Advancing Free Trade
for Asia-Pacific Prosperity

Symposium and Workshop on Technology Roadmaps to Promote Industry 4.0 in Developing APEC Economies

Summary Report

APEC Small and Medium Enterprises Working Group

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Executive Summary

Introduction

This document reports on the activities of the “Symposium and Workshop on Technology Roadmaps to Promote Industry 4.0 in Developing APEC Economies” and comprises two main sections:

1. The first one, “policy recommendation paper”, analyses the speakers’ presentations, the panellists’ discussions, and the reactions of the public to draw conclusions about the Public Policies that APEC economies may implement to foster SME adoption of I4.0 (Industry 4.0) technologies and the role of Roadmapping in this process.

2. The second one, “workshops results” analyses the workshops outcome to draw conclusions on how Roadmapping can be used for the purpose of fostering I4.0 technology adoption in SME in APEC economies.

Summary

The summary of the findings is presented in the form of a roadmap. This “Roadmap for implementing a roadmapping programme for I4.0 in SMEs” summarises in a visual structure the key findings of the Symposium and the workshops.

You can see the Roadmap in the next page.

A roadmap for implementing a roadmapping programme for I4.0 in SMEs

An invitation to work together for creating a better future

Why to implement a roadmapping programme for Industry 4.0 in SMEs?

- Ecosystem failure
- Ecology protection
- Technological disruption

The ecosystem is failing in providing equal access to the benefits of I4.0. (For example in SMEs and in gender equality)
I4.0 can have a positive impact in ecology protection by reducing energy, water and & raw material consumption.
Technological change is accelerating

A call for action for government to organise, coordinate and collaborate with Industry, academia and the wider society to create a better future

Roadmapping as a tool to aid collaboration, coordination and organisation of the sector.

VISION

Capture I4.0 benefits for society:
Enhanced quality of life: improve economies, provide more and better jobs (with purpose), better products and services, more connected people & things creating new value, enhance human possibilities for creativity, innovation, art, etc.

What to do?

Characteristics of the roadmapping programme

	t0	year 1	year 5	year 10
Aims	Kick-off the project, gain credibility and demonstrate impact with quick wins		Expand with emphasis in marginalised sectors, include big "tractor" companies and incorporate learnings from previous activities	Consolidate the programme and maximize impact in society
Roadmap (include customisation and updating processes)	10-20 pilot SMEs roadmaps	1 sector level I4.0 roadmap	Massification of SMEs roadmaps; Sub-sector level I4.0 roadmaps	Digitalisation of the roadmapping process
Stakeholders	Ensure participation of key stakeholders from government, academia, industry and society in general		Increase participation in time, creating a privileged space for strategic sector-level discussions	
Governance	Governance in charge of group of "notables" from government, academia and industry. In first instance lead by government.		Link to other processes and initiatives; Transfer the leadership to private sector or academia to ensure long-term stability. The group of "notables" could be nested in a association, cluster etc. but preferably out of government	

Note: include gender equality and environmental issues as drivers in all roadmaps

How to do it?

Required capabilities and resources.

	t0	year 1	year 5	year 10
Roadmapping capabilities	External experts to run the first roadmaps	Develop inhouse roadmapping capabilities	Create a guide or a mentorship programme to enhance roadmapping capabilities within the I4.0 community	
Funding	Ensure public funding for the first roadmaps and their projects		Ensure private matching funding for projects and initiatives emerging from roadmaps	

Time

Considerations

- Customise the roadmapping process to the context
- Revisit, revise and update the roadmaps constantly
- A sense of urgency is needed.
- High-level commitment is needed
- Monitor results (KPI)

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Summary Report

Introduction:

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2. The second one, “workshops results” analyses the workshops outcome to draw conclusions on how Roadmapping can be used for the purpose of fostering I4.0 technology adoption in SME in APEC economies.

The background of the project is:

Emerging APEC economies face challenges to adopt industry 4.0 technologies and to engage into technology intensive global value chains.

Coordination and alignment of key stakeholders (from government, academia and industry) within the sector is essential to face these challenges.

In that context, Technology Roadmapping (TRM) is a widely known methodology that can be used to align the public and private agenda for technology, innovation and public policies planning with a common vision developed between stakeholders.

This project aims to encourage SMEs to adopt 4.0 technologies in strategic industries for APEC economies, in order to make them more competitive and productive.

The structure of the report is shown below:

- Policy recommendation paper
  - Industry 4.0
  - Roadmapping

- Workshops results
  - Methodology
  - Drivers
  - Value
  - Resources
  - Roadmap for implementing a roadmapping programme for I4.0 in SMEs

Policy Recommendation Paper

The “Symposium and Workshop on Technology Roadmaps to Promote Industry 4.0 in Developing APEC Economies” consisted of 4 sessions. In each session, a Speaker made a 45–60-minutes presentation followed by a panel discussion (with 2-3 panellists in each session). The session was finalised by a Q&A sub-session in which the public was able to raise questions to the speaker and panellists.

The sessions topics (see table 1) were focused on two key subjects: a) Industry 4.0, and b) Roadmapping. The analysis of the speakers’ presentation, the panellists’ discussions, and the reaction of the public in this report are analysed and presented following these two key subjects.

Session and topic	Speaker(s) & panellists
Session 1 Industry 4.0: Types, Technology Transfer, Global trends	**Speaker:** Thorsten Korner (Robert Bosch GmbH) – GERMANY **Panellist 1:** Willson Deng (ArcStone Pte.) - SINGAPORE **Panellist 2:** Jonathan Blanchard Smith (Sami Consulting) – UNITED KINGDOM **Panellist 3:** Andres Arias (Vector Consulting) – COLOMBIA
Session 2: Importance of Roadmap, Public Policies and Collaboration between Stakeholders	**Speakers:** Rob Phaal & Eoin O'Sullivan (Cambridge University) UNITED KINGDOM **Panellist 1:** Yuta Hirose (Cambridge University) - JAPAN **Panellist 2:** Jonathan Castillo Alvarez (Quintil Valley) - CHILE **Panellist 3:** Bernard Killian (Incae Business School) – GERMANY
Session 3: Roadmapping Case Studies	**Speaker:** Ricardo Gonzalez (IfM Engage – Cambridge University) – MEXICO **Panellist 1:** Alfonso Avila Robinson (Tecnologico de Monterrey) - MEXICO **Panellist 2:** Pamela Antonioli (Hub de Innovacion Minero) - PERU **Panellist 3:** Rocio Fonseca Chamorro (InnovaChile - CORFO) - CHILE
Session 4: Industry 4.0 for SMEs	**Speaker:** Chao-Chiun Liang (Industrial Technology Research Institute - ITRI) – CHINESE TAIPEI **Note:** In this session there were no panellists.

Table 1: Sessions & participants

Industry 4.0

Sessions 1 and 4 focused on Industry 4.0, the former on “Industry 4.0: Types, Technology Transfer, Global trends” and the latter on “Industry 4.0 for SMEs”. The key learnings from these sessions are summarised below:

From Session 1:

Industry 4.0 Definitions (human participation & connectivity)

Mr Korner proposed the following definition of I4.0 contrasting what it is and what it is not (see table 2):

What is I4.0 NOT	What is I4.0
A ready to use standard product	Combination of industrial technologies with information technologies, generating a business enhancement.
A guaranteed success	It is an industrial revolution, but also an organizational / human revolution
A unique solution	Humans are principal actors for Industry 4.0 and their main tools are data
Forced automation	It is the vision of the Factory of the Future and the mission of the modernization of existing facilities

Table 2: What is I4.0 and what is I4.0 NOT (Korner)

One of the key learnings from what I4.0 is, is the emphasis on human participation, both as "principal actors" and the subjects of the revolution the I4.0 implies. This human-centric vision of I4.0 was a common concept constantly highlighted by other speakers and panellists along the Symposium.

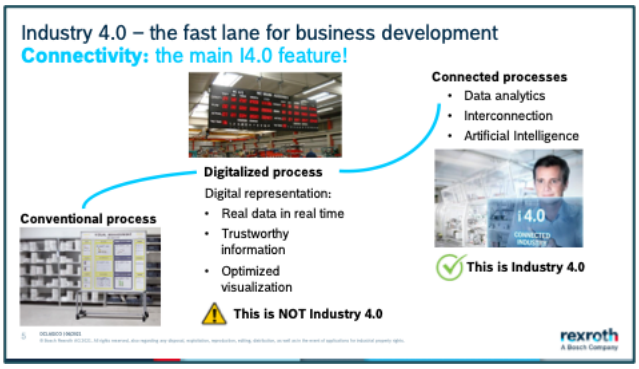

Figure 1: I4.0 & connectivity (Korner)

The second key learning is that I4.0 is about connectivity. This goes beyond data collection or digitalization, as described by Korner, connectivity is the main I4.0 feature (see figure 1).

Hence, I4.0 is about interconnected processes. Otherwise, it could be a conventional process or a digitalised process, but not I4.0.

I4.0 requires interconnected processes, not only within the organisation, but also outside the organisation (e.g. with suppliers and clients). It is about "working together" by sharing data and information.

3 steps for implementing I4.0 (connecting / visualisation, regulation & automatic control)

Korner proposes three steps or implementation phases for I4.0:

1. Step 1: connection / visualisation,
2. Step 2: regulation
3. Step 3: automatic control

The reason for proposing these steps is that "we cannot go from 1 to 100 in one step".

“In the first step, we connect machines & people, and we visualise data and we do it with hardware and software. This is a basic implementation, but it can lead to big profitable process enhancement”.

In step 2, “we have regulation, we have algorithms, we can program the machine to take decisions, without being intelligent, the machine can take decisions with some parameters we had programmed.”

“And the last step is automatic control, now we are talking about AI and machine learning, and anything else that has to do with the machine intelligence. This means that the machine is not only capable of taking decisions, but with the effect of each decision, the machine can also improve processes or modify them for us.”

When advancing from one step to the next one, it gets more profitable but also more costly and complex. However, by implementing only step 1 it is possible to achieve great benefits. Mr Korner, showed a case in Peru, in which a Bosch plant implemented Step 1 with savings above 28 million USD and with a relation investment / savings above 1 / 10, that means that for each invested USD they will get savings for more than10 USD.

Women participation in I4.0 (broader arena)

About the role of women in I4.0, Mr Korner commented that as I4.0 is a broader arena than I3.0, there is more space for women to participate.

“Historically, industry has been mainly related to masculine activities”

“Chances for gender equality are given by Industry 4.0 due to a broader task spectrum”

Considerations for SMEs (huge benefits from step1 alone and it is possible to interconnect conventional machines to I4.0)

Of special interest for this Symposium are SMEs. There were two messages from Mr Korner’s presentation that are relevant for SMEs. The first one, that it is possible to achieve great benefits from implementing simple / basic I4.0 solutions (Step 1) and, the second one, that you don’t need new and “state of the art” machines to interconnect them, as shown in figure 2 where a 1887 lathe was connected to I4.0.

Figure 2: 1887 lathe connected to the cloud

Role of people (usually what is missing is the human component, invest in training)

Willson Deng commented about the importance of focusing on people as the key to success in I4.0. The technology is there (software and hardware). What sometimes is not there is the human component, the creativity, the experience to integrate these

technologies into a holistic solution. Different people with the same data will propose different solutions (e.g., quality improvement, cost-savings, production speed, etc.), so the human factor is core to I4.0 and scarce.

“That’s why in Asia, there are huge investments in training and re-skilling people to be comfortable using these technologies and to have the hands-on experience in the manufacturing floor”.

Benefits (better, faster, and greener)

Mr Deng also pointed that I4.0 benefits include better, faster, and greener production. With low-hanging fruits like raw-material, energy, and water savings.

Assessment (know your company)

A I4.0 readiness level is important to assess the maturity of companies. Mr Deng gave the example of the SIRI (Smart Industry Readiness Index) that “benchmarks and allows each company to make a self-assessment of where they are in all these different categories, from people, to management to the tools, the equipment…” and “gives you a basic idea of where do I need to make my investments to maximize the use of I4.0”.

To adopt I4.0 you need to know your company.

The role of management is important to set the adequate pace to implement I4.0. “If management is too aggressive, you have a sub-optimal implementation.”

The future (I4.0 already here, the future is I5.0, 6.0 etc.)

Jonathan Blanchard Smith talk was about future trends in I4.0 The highlights of his presentation are:

Industry 4.0 is already here (is the present), so it is important to think in what is next (the future) and anticipate how we can take advantage of this future. There will be an evolution of I4.0 into I5.0, I6.0 etc. Some of the key points for this evolution are:

- More AI
- More connectivity (e.g., hyper-connected factories, dynamic supply chains)
- More robotics
- Customer-centric
- Highly customised
- Anti-fragile manufacturing
- Merging with bio-tech.

Opportunities for SMEs (they are the engine of the future)

Regarding the role of SME, Mr Blanchard mentioned that they are going to be able to succeed in this envisioned future as they are the “engine of the future”. In his view:

- SMEs are the disruptors of the status quo
- They have the ability to redesign processes and platforms
- SMEs can upend the perceived way of doing things

- SMEs move technology into the real world

Andres Arias talk was about his experience in Colombia developing a project with the Government to foster I4.0 adoption. He highlighted the following points:

Assessment

The importance of an assessment to know the level of digitalisation in an organisation, similar to the one previously mentioned by Mr Deng.

Strategic view (beyond operational applications)

The importance of the strategic view. I4.0 is not only an operational tool, could and should be used for strategic purposes and it has to be discussed in the strategic conversations of the company.

Training (re-skiling and up-skilling)

Mr Arias also discussed the importance of re-skilling or upskilling the "talent" and the value of learning by doing in this process.

Measure impact (not only financial impact)

Finally, he commented about financial impact: How to measure the "real" impact of the investment in I4.0, including social impact, environmental impact, etc.; and the need to take this into consideration while assessing an I4.0 investment.

Session 4:

Session four was delivered by Dr Chao-Chiun Liang. Dr Liang talked about his experience in supporting SMEs adopting I4.0 technologies at the Industry, Science and Technology International Strategy Centre, Chinese Taipei. In this session, there were no panellists. The key learnings from the session are:

Insights (data link the cyber and physical space, I4.0 value created via more speed & more precision, human innovation is essential in I4.0)

I4.0 Insights: Dr Liang presented 3 insights about I4.0:

a) Data intelligence: I4.0 is a plethora of tools, technologies, applications, techniques, etc. that cover and integrate the cyber-space and the physical-space. The key integrator of both spaces is data, hence the importance of data in I4.0
b) High value: the value of I4.0 is created in two axes; one is more speed and the other more precision.
c) Human innovation: similar to what was proposed by Korner, human innovation is a key component of I4.0 in Dr Liang's view. Technical integration alone is I3.0, technical integration + human innovation is I4.0. Again, we see that I4.0 is human-centric and goes beyond the technical sphere.

Opportunities (low-cost sensing and connecting, open-source toolkits) and Challenges (interface / integration and new business models)

I4.0 opportunities and challenges presented by Dr Liang:

a) Low-cost sensing and connection, which is like Mr Korner's step 1: connection and visualization.
b) Open-source toolkits.
c) Interface and integration issues: different data formats, incompatible APPs, different protocols, and different interfaces.
d) Business models issues: from reactive to proactive approaches, from one shot business to continuous services, from sale to agents to sale to users, from following specs, to product developer defining specs

Assessment and strategy (focus on key areas not all areas)

Dr Liang proposes a strategic process that starts with an assessment. The assessment comprises 4 categories: production management, smart machine, data storage and analysis, and market and supply chains. The assessment consists of 13 questions (see figure below).

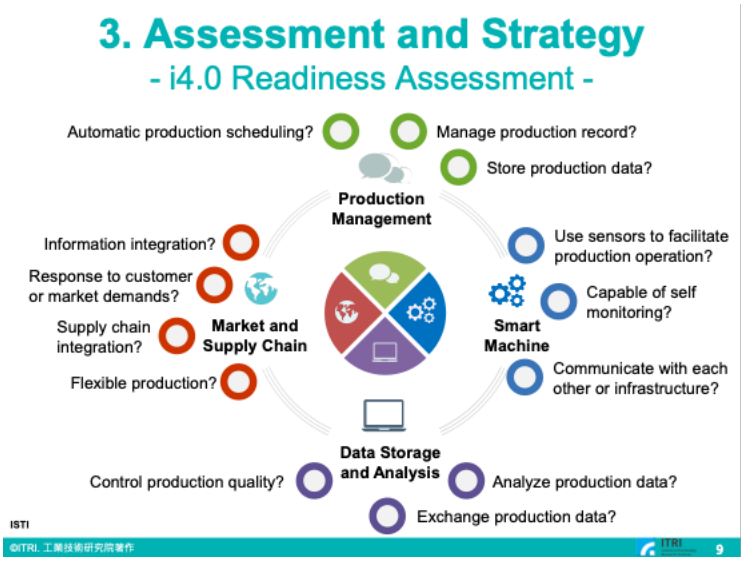

Figure 3: Assessment and strategy (Dr Liang)

Once the assessment has been done, what is suggested by Dr Liang is to focus on developing key areas, as opposed to developing all areas simultaneously. Compare both figures below:

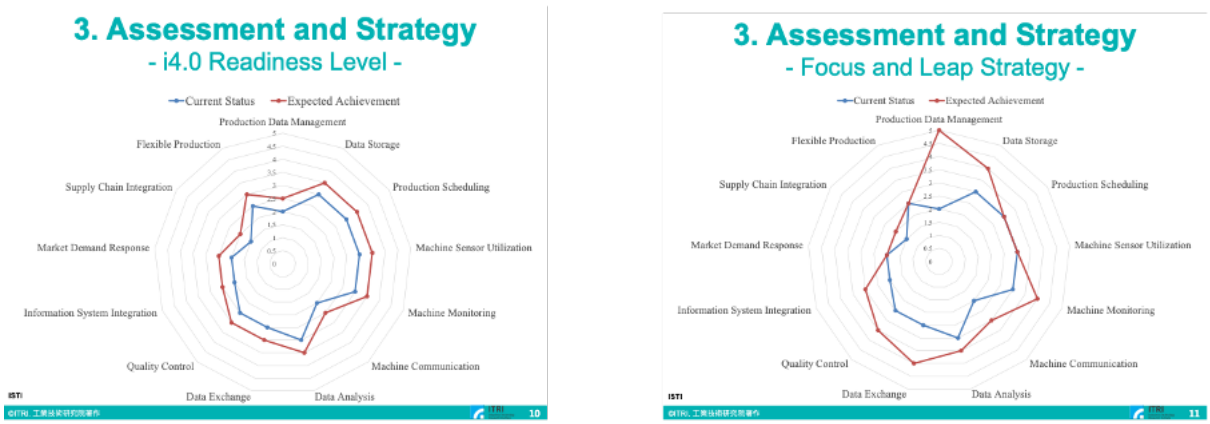

Figure 4: Developing all areas vs. focusing in key areas (Dr Liang)

This focus and leap strategy, as called by Dr Liang, will have the advantage of delivering palpable benefits that can justify the investment in I4.0.

Cases and demo sites (demonstrate benefits)

Cases and demo sites: to demonstrate the benefits of implementing I4.0 technologies in SMEs, Dr Liang proposes the use of success cases and demo sites. These should be considered by governments and agencies trying to promote I4.0. Regarding the demo sites, it is worth mentioning that these can be either cyber sites or physical sites.

Policies recommendations (demo / training sites, prioritise data collection, focus on rich data sectors)

Finally, Dr Liang proposes some ideas for public policies:

- Infrastructure: promote demo and training sites
- Enabling technology: encourage data collection and visualization, then analysis and intervention
- Focus on data rich industries
- Government investing in PPPs, R&D grants, matching funds, smart procurement, and prioritized sectors.

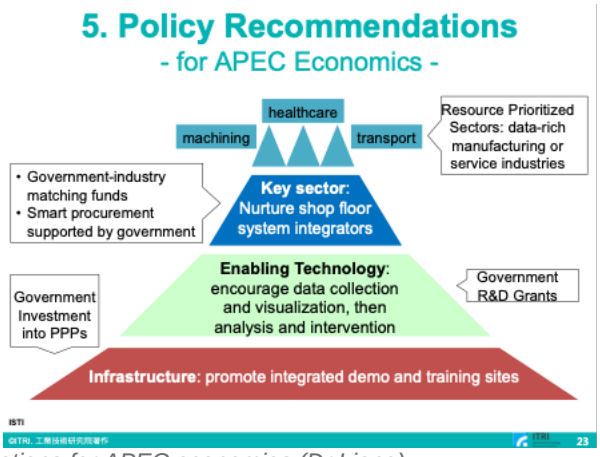

Figure 5: Policy recommendations for APEC economies (Dr Liang)

Roadmapping

Sessions 2 and 3 were about roadmapping, the former was entitled: “Importance of Roadmap, Public Policies and Collaboration between Stakeholders” and the latter: “Roadmapping Case Studies”.

Session 2

The speakers for session 2 were Dr Robert Phaal and Dr Eoin O’Sullivan. As panellists were Dr Yuta Hirose and Jonathan Castillo. The key learnings from the session are shown below.

Definitions (roadmap is a visual chronology of a strategic intent, Roadmapping is the process for creating a roadmap)

What is Roadmap and Roadmapping:

Roadmap is a structured visual chronology of a strategic intent, supporting alignment, integration, synchronisation, consensus, decision making, actions and resource allocation.

Roadmapping is a process guided by roadmap principles, typically leading to the development of a roadmap.

The roadmap starts with a canvas (or template) in which strategic narratives are captured and studied. See figure below:

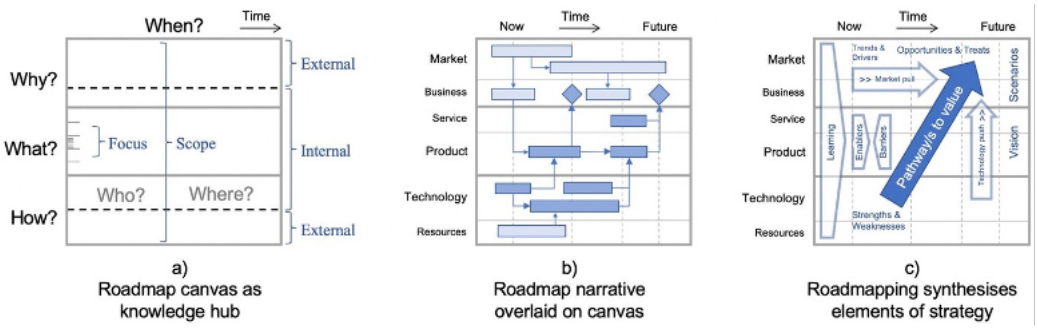

Figure 6: Roadmap canvas and content (Phaal)

A roadmap contains the three fundamental dimension of strategy: temporal synchronisation, functional alignment and hierarchical integration.

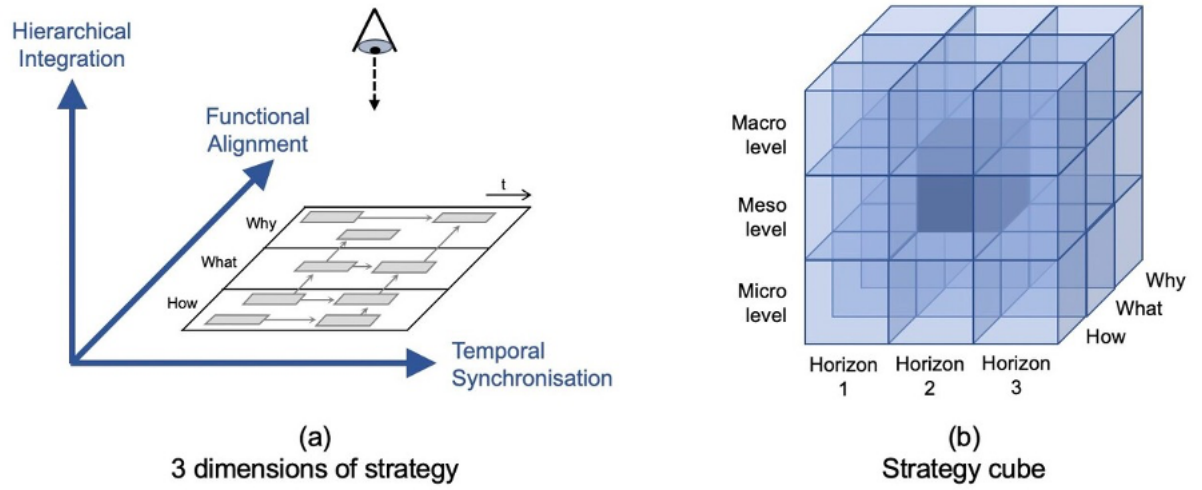

Figure 7: Three fundamental dimensions of strategy (Phaal)

Considerations for a successful roadmapping initiative

The roadmapping process can be seen as a service for more fundamental systems like strategy and innovation. De Laat and McKibbin (2003) proposed some consideration for roadmapping and foresight activities in general:

- Link to policy & Strategy
- Network / participation
- A sense of urgency
- High level commitment
- Vision and goals
- Involvement and ownership
- Link to decision makers
- Customise to fit the problem
- Sustain momentum with process
- Maintain flexibility
- Culture of openness
- Appropriate resources
- Iterate, review and update
- Monitor outcomes

Dr Phaal also mentioned the importance of workshops in the roadmapping process, the possibility of running virtual workshops and the value of templates to guide the process and discussions during the workshops.

Commonalities and variations between public & private sector (same principle, different motivations)

Dr O'Sullivan presentation was about the role of roadmapping in public policies. It started contrasting some of the variations between public and private roadmaps. See figure 8.

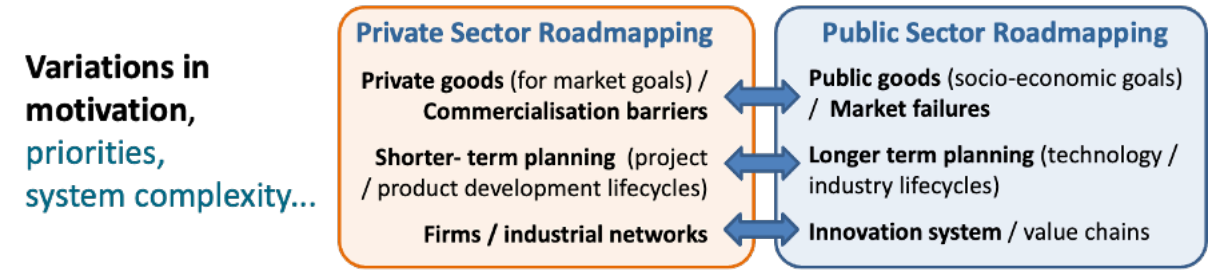

Figure 8: Variations between private and public roadmapping (O'Sullivan)

Other differences are that public roadmaps must focus on areas that government can influence and have different evidence requirements.

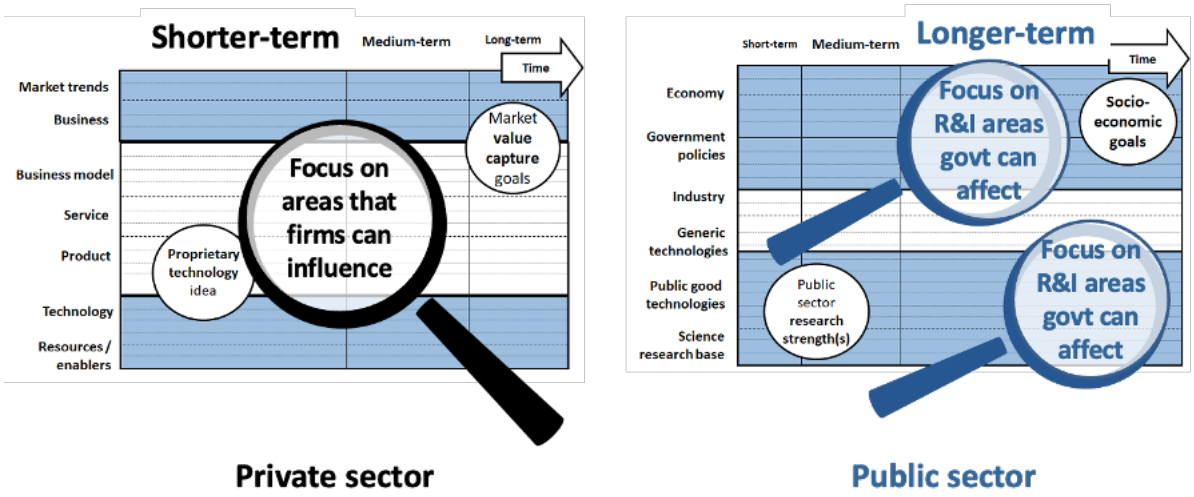

Figure 9: Focus areas for private and public sector roadmaps (O'Sullivan)

There are also commonalities between both roadmapping processes, e.g., same structure, same logic and same approach.

Uses of Roadmapping beyond technology

"Roadmapping increasingly used to strategize for innovation activities beyond tech development, e.g., enabling technology / tool development, standards development, infrastructure development, workforce development etc."

The importance of having the right people in the workshops

Having the right people involved in the roadmapping process is key for a successful deployment and implementation of this kind of processes. O'Sullivan included an example from I4.0 in Germany. The multi actor network was depicted as shown in figure 10.

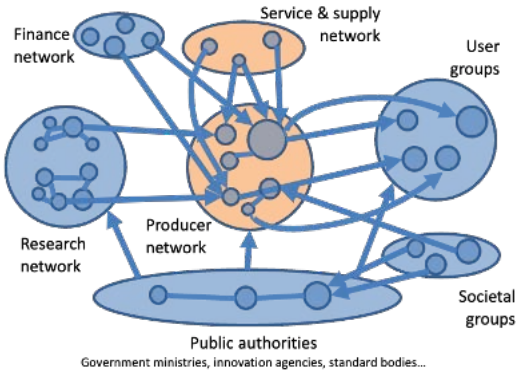

Figure 10: Multi-actor networks involved in socio-technical transitions (Geels, F. (2002))

Actionable public sector roadmaps (clear role of government, pay attention to policy cycles, get the right level of detail: iterate / adapt)

To develop "actionable public sector roadmaps" O'Sullivan suggests to...

- …identify a role for government: this can be done by diagnosing barriers and opportunities:
  - **What capabilities are required**? / To overcome barriers / address opportunities?
  - Why is there a **role for government**? / What market failures are preventing private sector solutions?
  - Benchmarking against **competitors**. / How do current/future capabilities compare with competitors?
- … pay attention to policy lifecycles, priorities, agendas:
  - Election cycles
  - Budget lifecycles
  - Spending reviews
  - Agency strategy cycles
  - Agency funding cycles
  - Programme lifecycles
  - …
- …get the right level of detail, scope, stakeholder confidence. However, it is not possible when commissioning roadmapping exercise to fully anticipate how complex the innovation dynamics might be. Hence, **analysis must be adaptive and iterative**, to ensure outputs are relevant, usable, trusted by users.

O'Sullivan proposes an agile adaptive roadmapping process for the public sector as shown in figure 11.

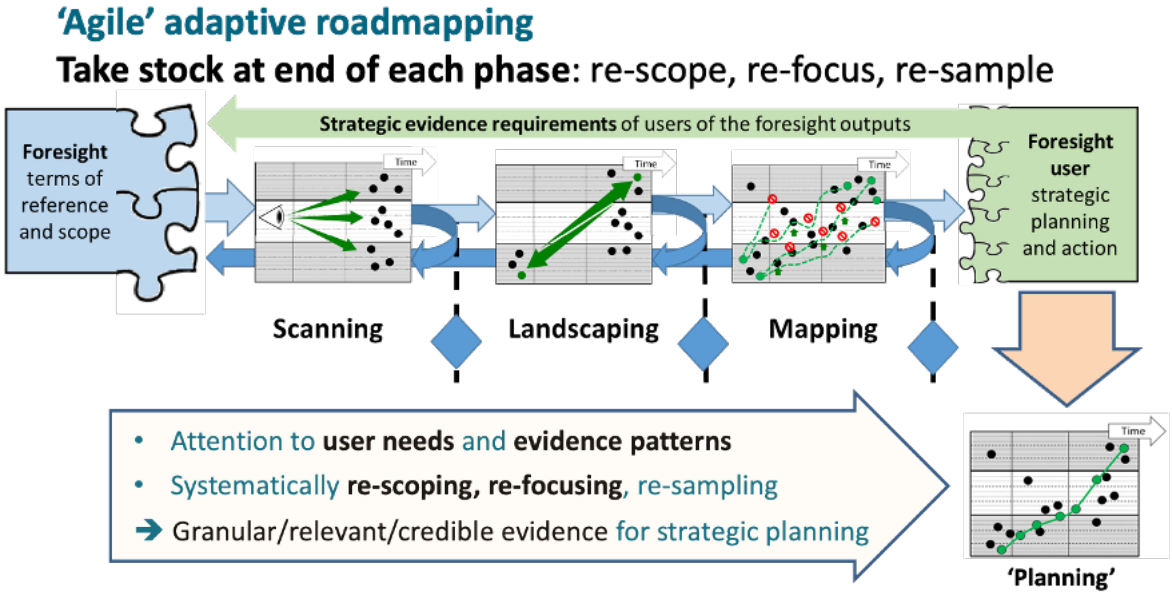

Figure 11: Agile adaptive roadmapping

Conclusions

The conclusions from Phaal and O'Sullivan are:

- There is value in using common frameworks, terminology, and methods or both public & private sectors
- Methods always need to be customised to context, including sector vs firm
- Systems-based roadmapping framework allows for 'zoom in & zoom out', enabling alignment, integration, and synchronisation
- Understanding pathways and associated enablers and barriers helps to identify scope for government support
- The explicit time dimension in roadmaps allows system dynamics (including policy) to be anticipated
- An adaptive / agile / flexible approach is recommended to accommodate uncertainty and enable learning

Yuta Hirose intervention included:

A definition of roadmap (a way of thinking)

"A way of thinking to decompose issues by using a multi-layered structure consisting of demand (why), value (what), supply (how), and timescale (when and where) to derive solutions and map out routes for realization."

Industry 4.0 to realise society 5.0 (I4.0 is a how, S5.0 a why)

From the Japanese perspective, following the structure of roadmapping, I4.0 is a "how" and the "why" is a super-smart society that they define as Society 5.0 (see figure below).

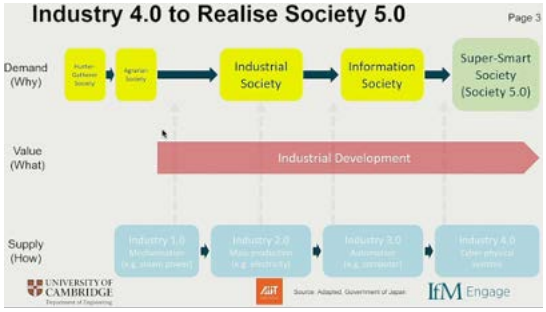

Figure 12: Industry 4.0 to realise Society 5.0 (Hirose)

A super-smart society or Society 5.0 (S5.0) is a “human centred society that balances economic advancement with the resolution of social problems by a system that highly integrates cyber space and physical space”.

Connected industries to accelerate the pace of I4.0 to achieve S5.0.

Connected industries: A vision from the Government of Japan of industries creating new added value and providing solutions to societal challenges by connecting a variety of data, technologies, people in the midst of global rise of the Internet of Things and Artificial Intelligence. It has 5 priorities:

- Automated driving and mobility services
- Manufacturing and robotics
- Biotechnologies and materials
- Plant / infrastructure safety management
- Smart life

Roadmapping in Japan (customisation, new approaches were developed)

In early 2000s government officials from Japan visited Cambridge to learn about roadmapping, specifically about T-Plan. They have customised the process that now consists of scenario for dissemination, technology overview and technology roadmap. They have continued to use the methodology and have created new approaches such as C-Plan for technology convergence and IS-Plan (innovation / strategy plan) for creating new businesses.

Jonathan Castillo intervention was about his role at the mining roadmap in Chile where he was general manager of Alta Ley, the corporation that lead the roadmapping activities.

Purpose of the mining roadmap (accelerate transformation)

The purpose of the mining roadmap in Chile was to “accelerate Chile’s transformation from a mineral producer economy to a mining technology exporter”

Two versions so far (a living document)

The first important milestone was the creation of the first mining roadmap in 2016 to address the most important technological and innovation challenges for cooper mining. This roadmap identified opportunities and capabilities in R&D to develop a technology-based supplier sector.

This roadmap guided an investment of 200 million USD in around 300 projects.

The second version of the roadmap was done in 2019 and focused on low-emission mining.

One of the key attributes of the mining roadmap is that it is a living document that changes and adapts to the needs of the new trends.

From session 3:

The speaker for session 3 was Ricardo Gonzalez-Nakazawa, the panellists were Dr Alfonso Avila Robinson, Pamela Antonioli, Rocio Fonseca Chamorro.

Ricardo's presentation was about roadmapping case studies that were conducted as part of this project.

Four case studies were selected, three of them from the IfM Engage, University of Cambridge experience and one from the available scientific literature in Technology Roadmapping. These cases are:

- CORFO (Chile): Sector level roadmapping
- Jamaica: Public policy roadmapping
- Road4FAME (EU): Roadmapping for exploring ICT innovation opportunities in manufacturing
- Singapore: Roadmapping in SMEs

A summary of the key findings after analysing the cases is shown below.

Conclusions about the use of Roadmapping (identify, explore, prioritise and develop opportunities)

The use of the roadmapping methodology in APEC developing economies to promote Industry 4.0 within SMEs could be relevant for:

a. Allowing each emerging APEC economies to identify the opportunities and challenges that the industry 4.0 revolution raises for their SMEs.
b. Creating a common vision of the future (where do we want to go?).
c. Identifying potential public policy responses and / or innovation opportunities (what can be done regarding the identified opportunities and challenges?).
d. Prioritising public policy responses and / or innovation opportunities.
e. Selecting the public policy responses and / or innovation projects to be implemented (what should we do?)
f. Enabling communication, collaboration and alignment between the government, the academia and the industry within each APEC economy.

How can roadmapping be applied APEC economies (customise, collect information, roadmap, revisit / update)

A recommended industry 4.0 roadmapping framework for developing APEC economies.

Based on the case studies analysis and the IfM Engage experience we propose the following roadmapping process (see figure a):

1. Adapt the process to the local context / needs.
2. Collect background information.
3. Sequence for sector-level Roadmap:
    i. Landscape & Synthesis workshops.
    ii. Prioritisation.
    iii. In depth analysis of prioritised opportunities (T-Plan or Topic Roadmap).
    iv. Implementation Roadmap.

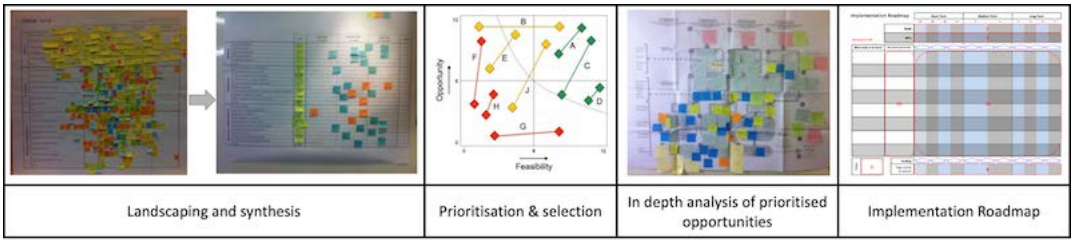

Figure a: Suggested approach for sector level roadmapping process

4. Sequence for individual in company roadmaps: T-Plan can be used to engage with individual firms in order to foster innovation and value-added activities. A process based on the OTR process (revised T-Plan process) can be used for this purpose (see figure b).

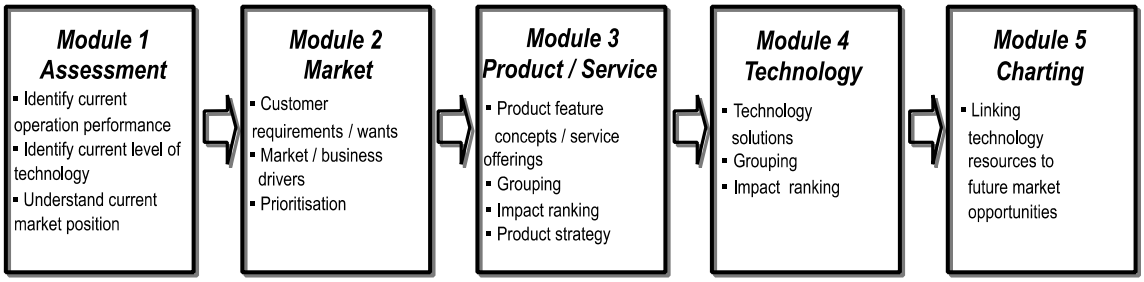

Figure b: Revised T-Plan process (Holmes & Ferril 2005)

5. Updating process: An updating process plays a key role in keeping alive the roadmaps and helps by:

    - Reminding us where we are going
    - Bringing new colleagues in
    - Deepening commitment
    - Deepening understanding
    - Updating / changing our view of the future

    The main aspects to consider in the updating process are (see figure c):

    i. Update your knowledge.
    ii. Implementation feedback.
    iii. Create / delete options.

iv. Roadmap redesign.

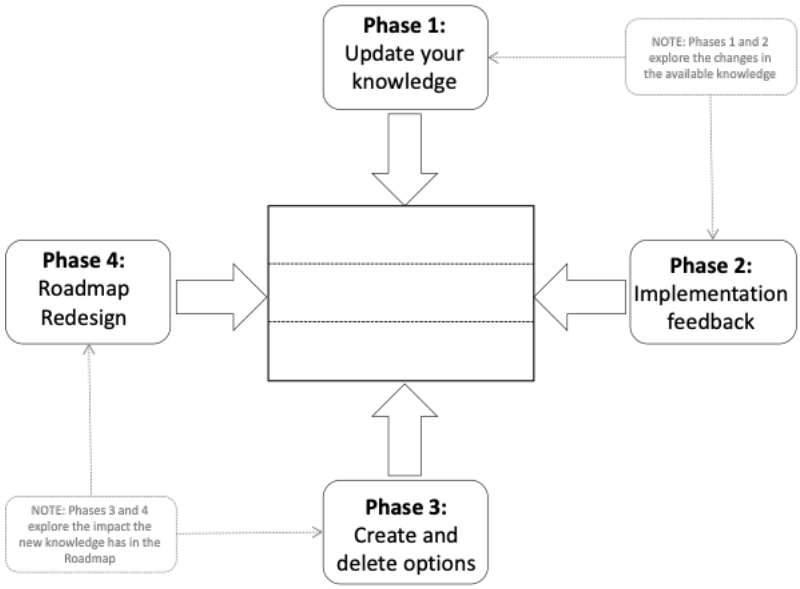

Figure c: Updating process

The process contemplates two possible roadmap implementation sequences, one for sector level and one for company level. The two sequences can be implemented simultaneously, or it is also possible to implement only one sequence (depending on the purpose of the roadmapping initiative). If the latter option is adopted and as the roadmapping initiative matures, the other sequence may be included. For example, if the programme starts with company level roadmaps it can evolve to cluster roadmaps and then to sector level roadmaps (a bottom-up evolution), if the programme starts with sector level roadmaps it can evolve to more specific roadmaps eventually reaching the company level roadmaps (a top-down evolution).

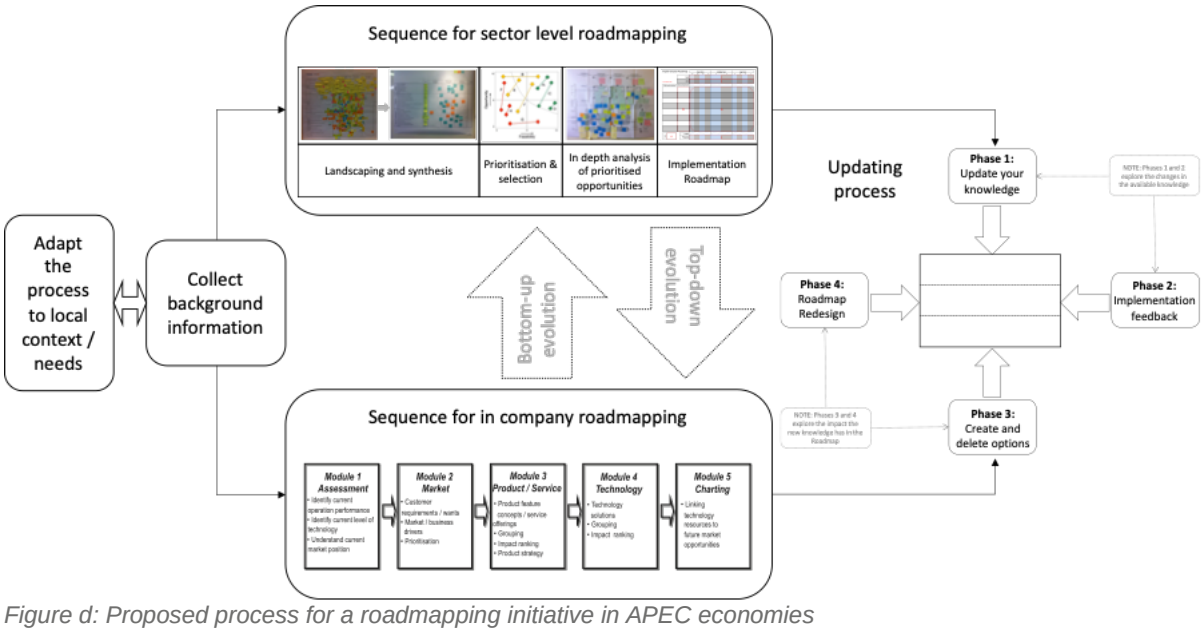

Figure d: Proposed process for a roadmapping initiative in APEC economies

- Plan for a long-term intervention: Strategy, technology, innovation and industrial development are long-term endeavours. When used in these contexts roadmapping is also a long-term activity.

- Funding: It is important to have the necessary funding for implementing the roadmap results. Knowing the available resources in advance could also inform the roadmapping process in order to adapt its portfolio to what is financially viable. Long-term funding deserves a special consideration (technology development and innovation tend to be long-term activities).

- Look for synergies between roadmapping and existing initiatives (e.g., economic development initiatives, innovation initiatives, SME's initiatives, industrial clusters, etc.). Roadmapping can be used to inform existing funding initiatives or programmes about funding priorities and opportunities.

- Develop local roadmapping capabilities: To sustain a roadmapping process in the long term it is essential to have local roadmapping capabilities. If they are not available, it is important to develop them along with the first roadmapping activities. Training and mentoring can be considered.

- Identify a champion and owner of the roadmapping programme. In some cases, it is useful for the champion / owner to be independent from government as political cycles may interrupt the continuity of the roadmapping initiative.

- Ensure industry, academia and public sector participation.

- Keep the roadmaps up-to-date: For updating information and decisions, but also to sustain and improve communication and collaboration.

Dr Alfonso Avila discussed about the academic perspective on foresight and on roadmapping.

Future literacy (needs to be thought & learned)

The idea behind future literacy is that future thinking is a competence that can be learned and should be part of our daily life. Up to now, the thinking and imagination of the future have been restricted to professionals such as futurists.

"In universities, it means that we have to provide students with future skills and those skills can help them to address the challenges that society is facing. Thinking about the future should be part of any education programme. At the core of this idea are the tools."

Roadmapping (part of the futurist toolkit)

Roadmapping is one of the tools that belong to the futurist toolkit. The importance of these tools is that industry and government leaders suffer from short-termism.

One of the key aspects of roadmapping is the integration of multiple perspectives, which enriches the solution ideation. The roadmap is more than the outcome; it is about the multidisciplinary ideation process that creates this outcome.

Pamela Antolini:

Roadmapping (Active participation)

Experience of the mining sector: One of the key aspects of roadmapping is that it is based on active participation. The collaboration between different actors is important to keep the roadmap alive. “We need to be connected”. Active participation also allows to face common challenges. “We have huge common challenges that are shared not only in the mining sector in Peru, but around the world. We are dealing with climate change, with social responsibility”.

Roadmap is a tool that allows to gather different points of view, “in the mining sector there is a huge opportunity to develop initiatives with active participation, for example, with a regional approach or a value chain approach. It helps to have a common vision to build the future together.”

Rocio Fonseca:

Challenges (4 waves: social, sanitary, economic, and environmental crises)

Chile is facing 4 big waves: a) social crisis “Chile had a social crisis at the end of 2019”, b) Sanitary crisis: “now we have this global crisis, the sanitary one”, c) economic crisis, d) climate change: “we cannot forget the fourth wave, that is climate change, is the biggest one and Chile is one of the most affected economies.

“So how can we innovate, how can we create different roadmaps by working in parallel to help the entire ecosystem to: survive, to reconvert their economic matrix and dynamize the businesses that are doing well. So, when we see innovation, when we see collaboration and we start to create these roadmaps we have to start thinking about short, mid and long-term. Of course, we have to think in the long term, but we have to sustain our economy right now and we have to use innovation to do that in the short and medium-term”

The role of government (be a bridge, connect the dots)

“As a government we are acting like a bridge, connecting dots where nobody is connecting them today. More of the 70% of start-ups fail not for the lack of money but for the lack of training and connections. So, for us the collaboration is the key factor.”

From roadmapping to action

“For us creating the roadmap is the first step, but we have to move into action, implementing, we have to have quick-wins, long term goals and have KPI to monitor all the steps and results”.

Workshops results

This section of the report presents the results of the workshops.

Introduction to the workshops

Three workshops were designed and delivered as part of this project. The workshop's design and characteristics are shown below.

Objective:

Support APEC economies in implementing a Roadmapping Programme for the adoption of Industry 4.0 technologies in SME

Expected result:

A long-term plan that can help and guide APEC Economies interested in developing a roadmapping initiative / programme in Industry 4.0 for SMEs.

Focus:

- APEC Economies
- Roadmapping
- Industry 4.0
- SMEs

Architecture:

R2 (Roadmapping Roadmapping) This architecture provides a framework for planning a Roadmap initiative. It is a "Roadmap for Roadmapping initiatives". (See proposed template in figure 14)

Taxonomy:

Public policy

There are two generic taxonomies for the R2 architecture. One is for market-oriented organisations and the other for public policies. In this case, the latter was selected.

Time horizon:

10 years

A ten-year time horizon was defined as this is the time it takes for a public policy roadmapping programme or initiative to start, grow and consolidate.

Workshop agenda:

The following agenda was designed for the Workshops.

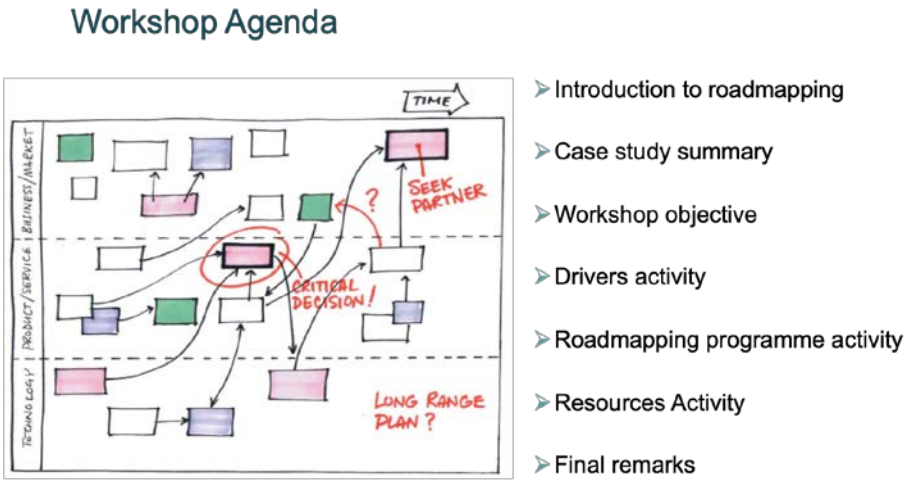

Figure 13: Workshop Agenda

Participants:

33 participants were invited (11 per workshop). From them, 25 attended the workshops (5 in the 1st workshop, 10 in the 2nd workshop and 10 in the 3rd workshop). Participants were selected / appointed by APEC and the Ministry or Production of Peru, including participants from:

- Academy
- Industry
- Government

Workshops:

3 workshops were delivered in the following dates:

- Workshop 1: June 24 (Afternoon in Peru)
- Workshop 2: June 25 (Morning in Peru)
- Workshop 3 June 25 (Afternoon in Peru)

Duration of each workshop:

2-3 hours approx. per workshop

Briefing note:

IfM Engage prepared a briefing note that was sent to participants 1 week before the workshops. This briefing note included the key results from the Case Studies Report, joining instruction and a pre-workshop questionnaire for the participants.

Background research:

Four case studies had been conducted to analyse the implementation of sectorial roadmap initiatives. The case studies will be presented at the Symposium before the workshops. Additionally, a brief summary was included in the briefing note and presented at the beginning of each workshop.

Pre-workshop questionnaire:

A brief questionnaire was included in the briefing note in order to provoke participants to think about how to implement a roadmap initiative in an APEC Economy.

Place

Workshops were held on-line.

Two platforms were used, one for audio and video; and the other for virtual templates and virtual sticky notes:

- Zoom: for communication among participants and the facilitator. This platform was provided by the organisers.

- Mural: The mural platform was used to simulate templates and sticky notes. This platform was provided by IfM Engage.

Template

A roadmapping roadmapping (R2) template was used (see example on figure 14).

The R2 template is for supporting governments and organisations to plan a long-term Roadmap Initiative.

The template was customised according to the objective and focus of the project and based on the results of the case studies analysis and learning.

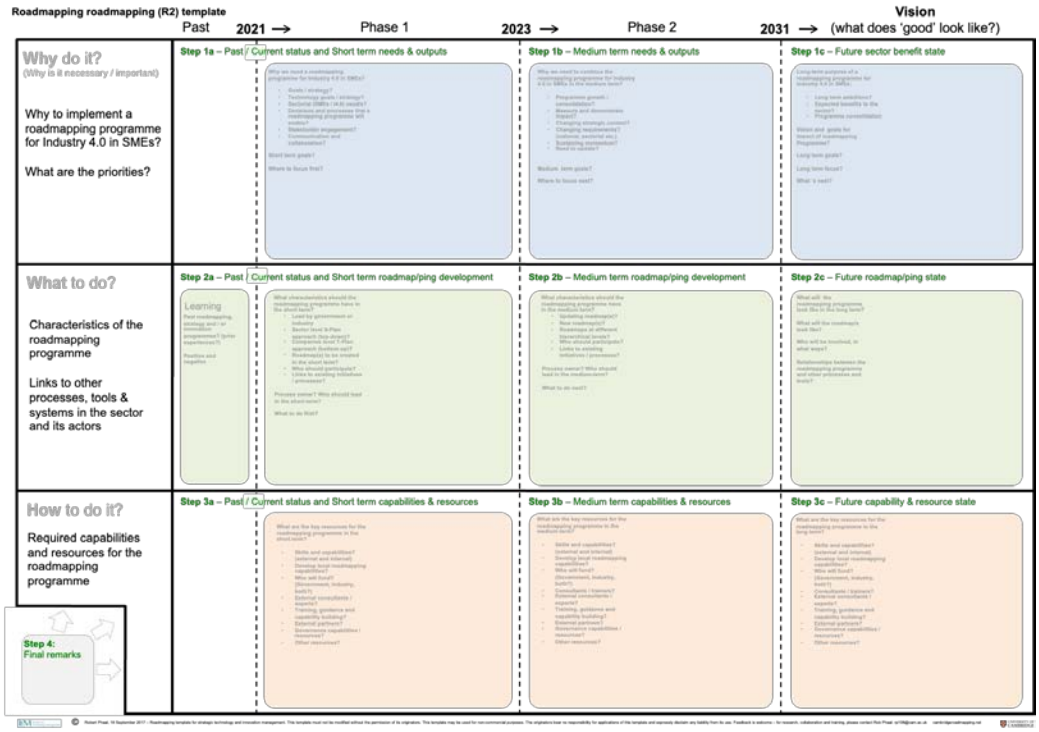

Figure 14: Roadmap template

Workshops' analysis.

The process that was followed for the analysis of the information gathered during the workshops is explained below.

Clustering and synthesis of each workshop:

During the workshops the perspectives of all participants were captured. During the analysis of the workshops' outcome, those perspectives were grouped in clusters and prioritised according to their relevance to the objective of the workshop.

These perspectives were then captured in a preliminary synthetised roadmap (one per workshop). These roadmaps are shown in figures 15, 16 and 17.

Preliminary roadmap: Workshop 1

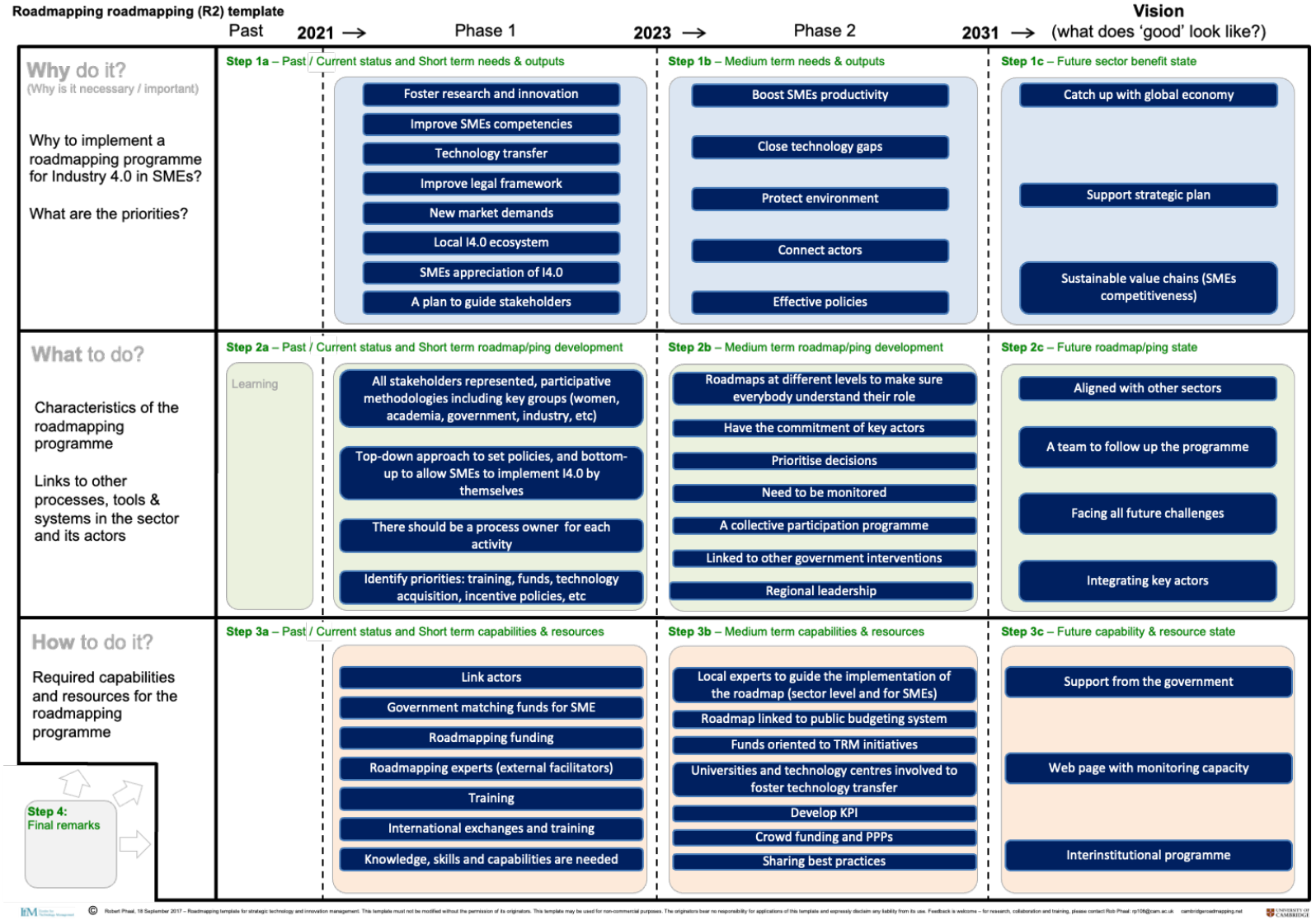

Figure 15: Preliminary roadmap WS1

Preliminary roadmap: Workshop 2

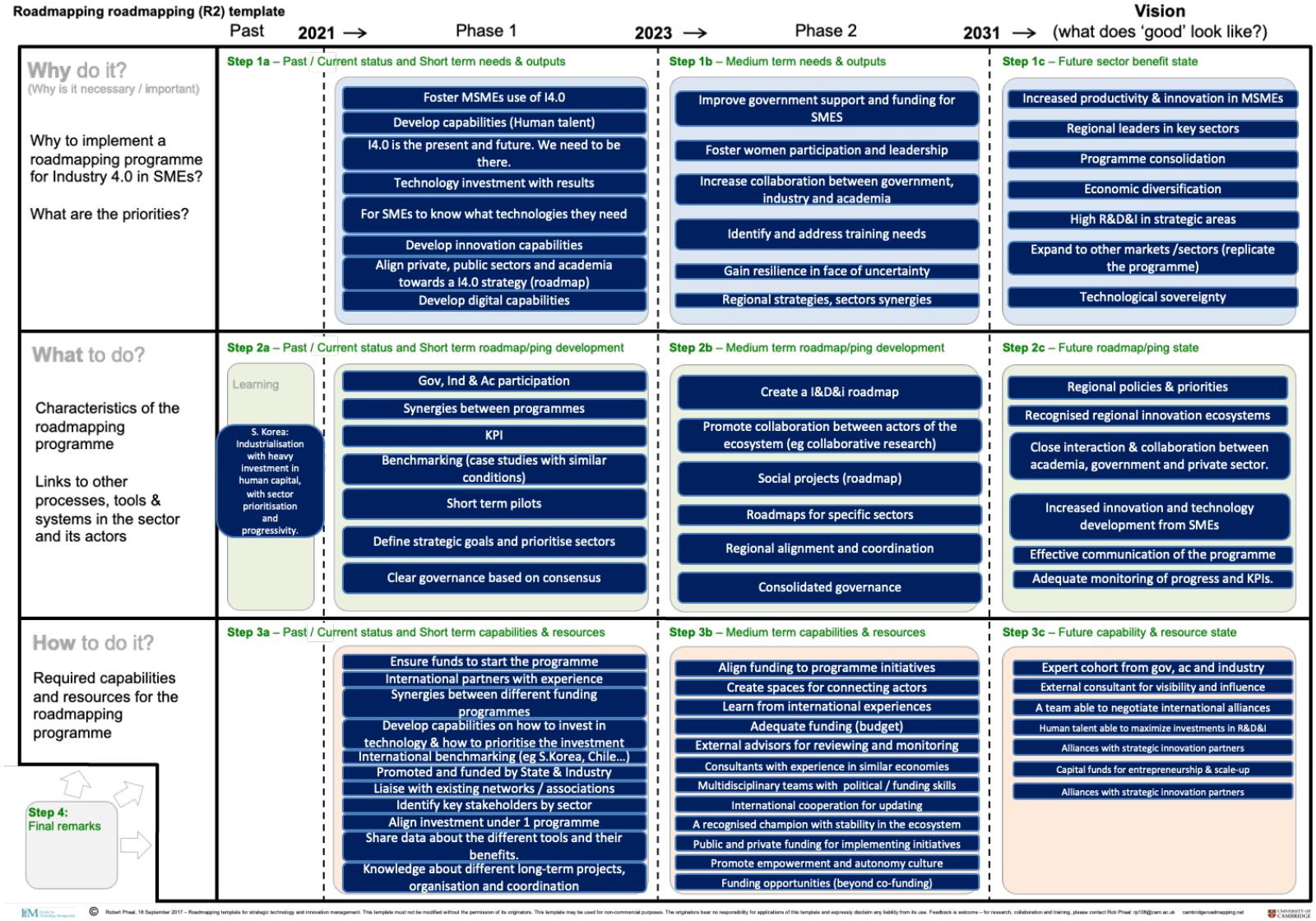

Figure 16: Preliminary roadmap WS2

Preliminary roadmap: Workshop 3

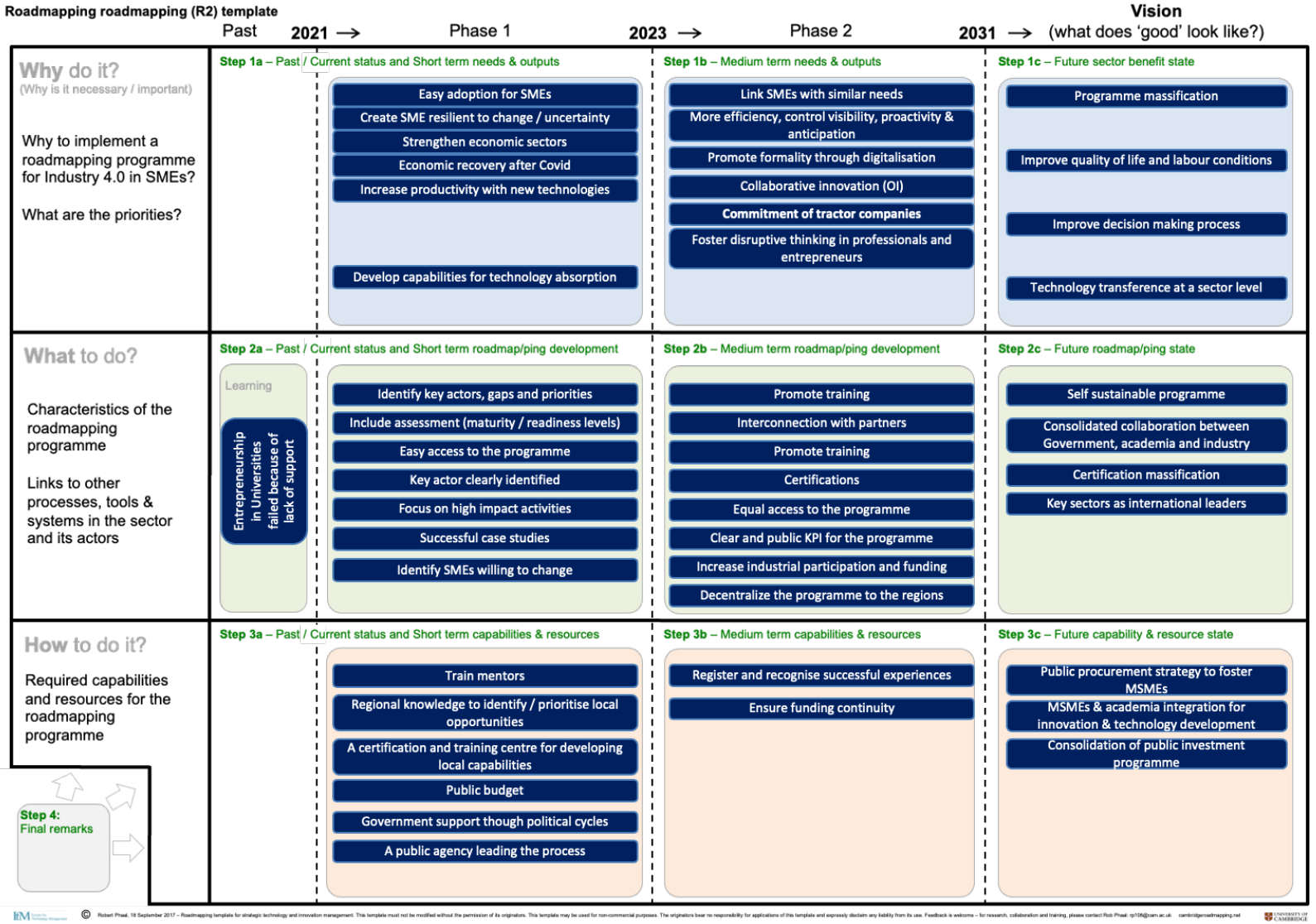

Figure 17: Preliminary roadmap WS3

Merging results in one final roadmap

The three preliminary roadmaps were merged into one final roadmap. This roadmap was complemented with information that was captured from the symposium (speakers and panellists) and with the information collected in the Case Study Report.

In this step, the aim is not only to summarise the collected information but to make sense of all the perspectives to reach a coherent final roadmap.

Drivers

The first analysis corresponds to the Drivers layer, which is the top layer in the roadmap. This layer answers the question “why?”; in the case of this project to the question “Why implement a roadmapping programme for Industry 4.0 in SMEs?”

Four categories of drivers were identified:

- **Ecosystem failure:** The I4.0 ecosystem is failing in providing equal access to the whole of society. Specially remarked during the sessions and workshops was the case of the SMEs that are frequently marginalized from I4.0. Another example is related to gender equality where women are underrepresented in the sector. It is easy to imagine other parts of society that are marginalized from the benefits of I4.0, for example, indigenous communities, communities with limited or no access to internet, etc.

- **Ecology protection:** As mentioned by Jonathan Blanchard, either we use science, technology, and innovation to prevent ecological collapse, or we return to a pre-industrial era. Industry 4.0 can contribute to this effort by reducing energy, water, and resources consumption.

- **Technology disruption:** The accelerating pace of change of technology and the disruption that this causes in society demand more and better future thinking. As mentioned by a panellist, we need future literacy. Roadmapping is a tool that can help to think about the future and what to do next.

- **Potential benefits of I4.0:** Finally, it is impossible to overlook all the potential benefits that I4.0 can deliver to society at large. For example, creating better products and services. Furthermore, I4.0 can improve quality of life by creating more and better jobs (with purpose), by automating rutinary activities, freeing time for more meaningful activities, connecting people and things, creating opportunities for creativity and innovation, etc.

These four drivers constitute a call for action and government intervention in coordinating, organising, and collaborating with industry, academia, and the wider society to create a better future based on the opportunities and challenges that I4.0 revolution is presenting to the global community in general and to the developing economies and SMEs in particular. See figure 18.

Figure 18: Drivers, first layer of the roadmap

Value proposition

The second layer or middle layer of the roadmap corresponds to the value proposition layer. In this layer the roadmap answers the question "what" in the case of this project "What to do? -Characteristics of the roadmapping programme".

Four categories were identified in this layer:

- **Aims:** the aims are divided in time horizons:
  - In the short-term: Kick-off the project, gain credibility and demonstrate impact with quick wins
  - In the mid-term: Expand with emphasis in marginalised sectors, include big "tractor" companies and incorporate learnings from previous activities
  - In the long-term: Consolidate the programme and maximize impact in society
- **Roadmap:** these activities are arranged in a timeline, from present to future the activities are:
  - 10-20 pilot SMEs roadmaps
  - 1 I4.0 roadmap
  - Massification of SMEs roadmaps
  - Regional level I4.0 roadmaps
  - Digitalisation of the roadmapping process
- **Stakeholders:**
  - Ensure participation of key stakeholders from government, academia, industry, and society in general
  - Increase participation in time, creating a privileged space for strategic sector-level discussions
- **Governance:**
  - Governance in charge of group of "notables" from government, academia, and industry. In first instance lead by government.
  - Link to other processes and initiatives
  - Transfer the leadership to private sector or academia to ensure long-term stability. The group of "notables.2 could be nested in an association, cluster etc. but preferably out of government

Some recommendations are worth considering:

- It is suggested that roadmaps include gender equality issues as drivers
- It is suggested that roadmaps include environmental issues as drivers
- It is recommended to customise the roadmapping process to the context

- Revisit, revise and update the roadmaps constantly
- A sense of urgency is needed.
- High-level commitment is needed
- Monitor results (KPI)

See the value layer in fig 19.

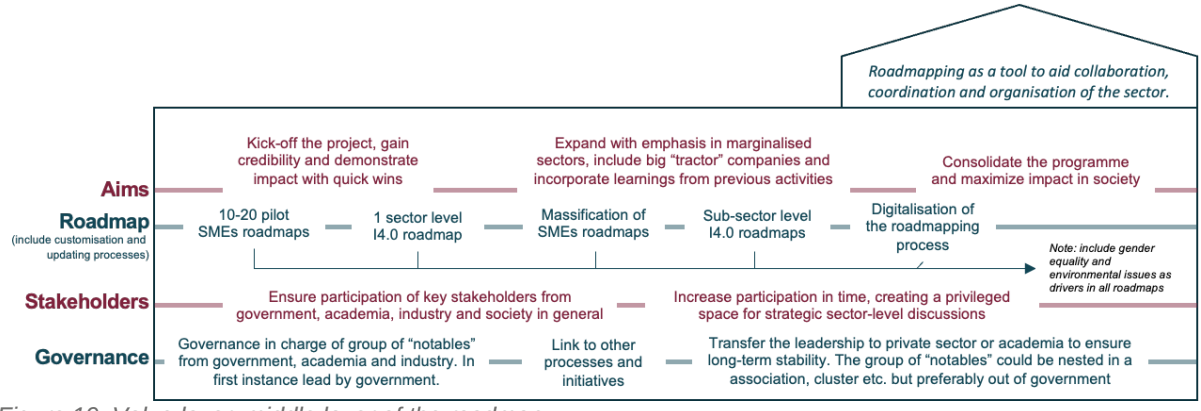

Figure 19: Value layer, middle layer of the roadmap

Resources:

The final layer is about the "how" in the case of this project, the question was: "How to do it? -Required capabilities and resources". This layer included two concepts:

- **Roadmapping capabilities:**
  - External experts to run the first roadmaps
  - Develop inhouse roadmapping capabilities
  - Create a guide or a mentorship programme to enhance roadmapping capabilities within the I4.0 community
- **Funding:**
  - Ensure public funding for the first roadmaps and their projects
  - Ensure private matching funding for projects and initiatives emerging from roadmaps

See the resources layer on figure 20.

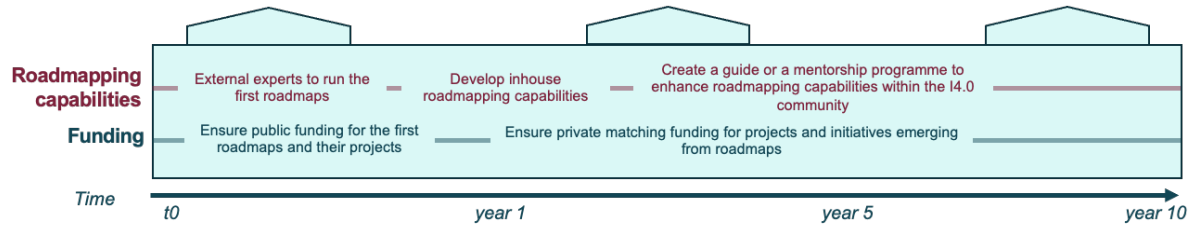

Figure 20: Resources, bottom layer of the roadmap

A roadmap for implementing a roadmapping programme for I4.0 in SMEs

In the following page, the complete roadmap can be appreciated.

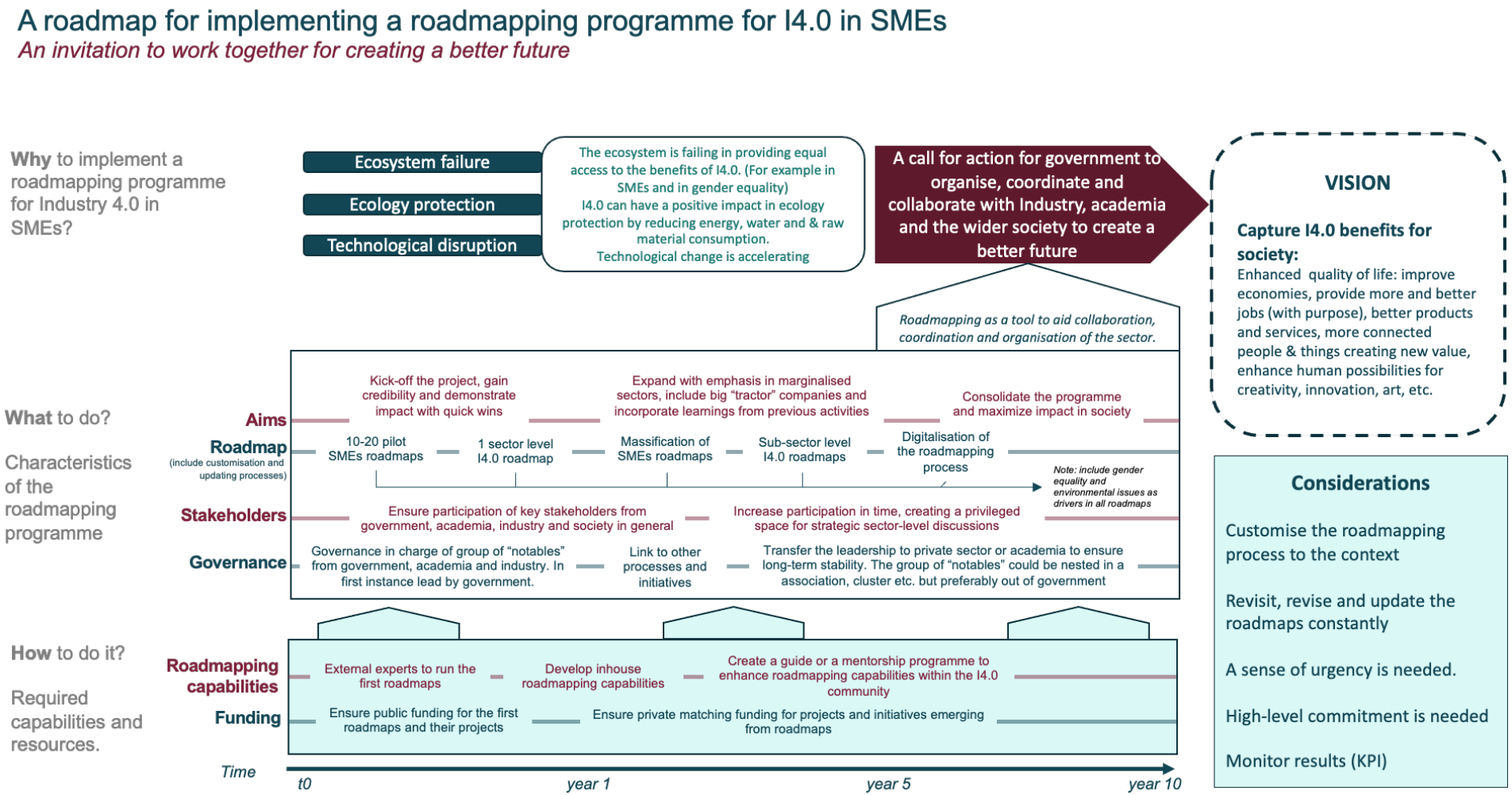

Figure 21: A roadmap for implementing a roadmapping programme for I4.0 in SMEs