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Global foresight: Lessons from a scenario and roadmapping exercise on manufacturing systems

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ABSTRACT

Geographical dispersion, organisational and cultural differences, and the diversity arising from a large number of participants are all characteristics of international foresight exercises. In this paper, the authors develop four principles for the design and management of global foresight exercises building on the experience of designing and managing the Intelligent Manufacturing Systems (IMS) 2020 project. The first principle is *understanding interconnected innovation systems.* This principle ensures that participants position the foresight exercise and their own activities in a global context. The second principle is *responsiveness towards diverse languages and cultures*. This principle strengthens commitment and encourages learning and creative problem solving. The third principle is *capacity to reconfigure international networks.* This principle is about taking advantage of existing organisational structures and facilitates timely and efficient mobilisation of stakeholder communities. The fourth and last principle is '*glocal*' *impact orientation*. This principle ensures that foresight activities are connected to both local and international decision-making structures. Overall, due to the heterogeneity of global projects, all four principles must also be implemented in keeping with a scalable design approach.

1. Introduction

Mounting effective responses to many major societal challenges usually requires coordinated efforts that extend beyond regional and national boundaries [1]. In this context, any deployment of future oriented technology analysis (FTA) must be able to take into account trans-border, often global considerations. This paper addresses FTA and in particular foresight design and management in an international context. The aim is to draw lessons for international foresight processes on the basis of a specific international foresight project on intelligent and sustainable manufacturing systems.

Foresight has been applied at global and regional levels to support the design and implementation of policies and strategies. Examples range from the European Commission through the Framework Programmes and its Joint Research Centre, the OECD through its International Futures Programme, UNIDO through its Technology Foresight Initiative, the Asian-Pacific Economic Cooperation (APEC) Centre for Technology Foresight, the UK Foresight Horizon Scanning Centre, the Risk Assessment and Horizon Scanning (*RAHS*) programme in Singapore, among others. Many of the specific projects undertaken by these different organisations are well documented. However, less attention has been paid to the theory and

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practice of the design and management of international foresight processes. This article aims to begin filling the gap by analysing the authors' experience with an international foresight project. On the basis of this case study the authors outline what they consider to be the necessary preconditions and managerial approaches that are likely to be conducive to a successful international foresight project.

Projects of this kind are usually characterised by geographical dispersion, organisational and cultural differences, and the large number of diverse participants, each with different expectations and needs [2]. As a consequence it is essential to take these factors into account in the design and management approaches used for such projects. Section 2 examines the available literature on international foresight management and conceptualises design and managerial issues particularly relevant in the international context. Four principles for global foresight design and management are identified. The ways in which these have been dealt with in practice are outlined in Section 3 on the basis of a case study, an international FTA project addressing the future of intelligent manufacturing systems (IMS). Section 4 outlines the lessons learned from the authors' experiences in designing and managing the IMS 2020 project. The authors develop four principles that they believe should be taken into account when designing and managing an international foresight undertaking. Section 5 considers, on the one hand, how FTA projects like IMS hold out the promise of achieving better international coordination and joint preparedness for future grand challenges. While on the other hand, the complicated attributes of international foresight exercises necessitates careful consideration of relevant design and managerial challenges in order to take into account scale, culture, timing and institutional constraints. Section 6 summarises the main conclusions.

2. Global foresight design and management

The design and management of global foresight projects, like any significant international undertaking, calls for clarity, unity, integrity and coherence [3–5]. Further design requirements are introduced if the project aims to incorporate international research, innovation systems [6] and the diversity of stakeholders. Our contention is that these design requirements can be met on the basis of four guiding principles for global foresight. These principles build on the international foresight literature and our experiences with a global foresight exercise that is described in Section 3. The four principles are:

- Understanding interconnected innovation systems.
- Responsiveness towards diverse languages and cultures.
- Capacity to reconfigure international networks, and
- a 'glocal' impact orientation.

2.1. Understanding interconnected innovation systems

Before starting any foresight venture is important to have a clear idea of the system being analysed and related interconnected systems (e.g. social, technological, economic, environmental, political, value, cultural, among others) [6]. Managers of international exercises must also take into account the distinctiveness of local, regional and national sub-systems around the world. Such understanding may be supported by earlier research and available databases. At the same time, a spectrum of foresight methods can be applied to develop a better understanding of possible future developments of the systems under analysis [7].

In this context, examining system properties in the international context in which the exercise takes place supports the development of a common understanding of different, even diverging, viewpoints. This analysis promotes the shaping of joint objectives and the overall scope of the exercise. Hence, the further development of transnational research and innovation collaboration benefits from experiences with the vertical coordination of multi-layered research and innovation systems. The same is true with respect to the horizontal coordination between research and other policy areas. Both struggle with temporal coordination of policies [8].

Therefore, to enable an appropriate design, implementation and management of an international foresight exercise, the ability to shape a common path to follow becomes important. This should be built upon a collective vision, which considers the views and actions of involved individuals and their institutions, as well as resources which should be developed and mobilised. Such an achievement ensures ownership and that action is taken upon results. Gertler and Wolfe [9] corroborate this point by outlining that foresight processes should be seen as socially organised learning processes which involve learning by individuals, by organisations and by institutions. Moreover, the authors' claim that a collective vision should be shaped by building upon individual views, actions and interactions with larger institutional structures.

2.2. Responsiveness towards diverse languages and cultures

Diversity among global participants and their differing constituencies set a coordination challenge that calls for responsiveness towards all stakeholders' of an exercise [10]. Cultural differences, language barriers, institutional practices, regulatory frameworks, capacities and capabilities of participants to contribute as well as more practical difficulties, such as different time zones and geographical distances; all require prudent and balanced management [11].

In the design phase is important to structure aspects such the interactions between people (e.g. participants, stakeholders, policy and decision makers, among others) and communication processes [12]. Along the same line, the ways in which workable agreements will be achieved should be prepared from the outset building upon shared understanding as well as collective and creative knowledge. Salo et al. [13] agree when they affirm that one of the defining features of foresight is the creative generation of synthetic knowledge whereby future-oriented expectations are jointly produced, combined and assimilated through various inputs and critical reflection. In other words, mutual learning. At the same time, the process must be designed to cope with shifting objectives and stakeholders' expectations during the implementation phase (i.e. the so-called responsiveness of the process) [13]. This means that relevant stakeholders should be involved in some form of dialogue (methods vary) across different stages of the process to share their views regarding achievements and their meaning, before proceeding to the following stages of an exercise [14].

Therefore, there is a clear need to ensure expectations are managed in line with the objectives of the exercise while being adaptive both in terms of process (combine open and collective with closed and expert-driven stages) and results (different options for different audiences, and recommendations which are adaptive to change).

Könnölä et al. [15] claim that stakeholders' diversity[1] is important to foster innovation capabilities through the creation of viable alternatives (scenarios) that escape the existing dominant designs and techno-institutional lock-ins. Ultimately this allows the system to become more adaptive. In this context it is necessary, the authors argue, to enable a systematic analysis of how different (weak) signals refer to one another or what they mean to different stakeholders.[2] This is important because it focuses diverse inputs by soliciting signals that convey ideas about future innovations aligned with the systemic and action-oriented nature of innovation processes, instead of less focused future-oriented statements. Salo et al. [13] agree when they claim that an effective communication process with all stakeholders involved, including those in the initial phase of information collection, is paramount to yield both ownership and use of results.

Managing diversity and interactions as well as communication and behavioural aspects should be done in a way that is clear and coherent from the beginning of an endeavour and to all who are involved throughout the process [12]. Furthermore, it is important to make sure that these aspects are integral to both the strategic and the operational aspects of the exercise, and applied equally by all partners in alignment. Costanzo [16] reinforces this point, claiming that nimbleness, visible and structured processes, and extensive communication glued together by a focused management team, form an important core capability that impacts on the ability of organisations to undertake strategic foresight.

It is often the case that an exercise is shaped together with the client, project partners and other key stakeholders. In the international setting, those involved in the discussions may not be acquainted with foresight, or have different interpretations of it. There can be concerns, for instance, regarding the decision-making power of stakeholders due to the bottom-up aspects of the process. It is important, therefore, to share and overcome such concerns before proceeding and further shaping an exercise.

2.3. Capacity to reconfigure international networks

The ability to build upon both formal and informal international networks can help combine existing knowledge in novel ways. It also allows creativity to take place and to embed the exercise in the systems it is part of. Towards this end, it may be crucial to ensure multiple communication channels to enable knowledge to flow, interactions to take place and workable agreements to be achieved [17]. Here one of the major challenges is to embed the global foresight exercise in different local, regional and national systems as well as within international sectoral networks and institutions. The establishment of strong connections with existing formal and informal networks,[3] particularly those contacts cultivated over the years [18], can provide a relevant starting point.

2.4. A 'glocal' impact orientation

Many researchers specialised in international management [20,21] have argued for 'glocalization' as the transformation of global and local interests into a new or unique form of operating that 'continually renews itself by balancing the organisational tensions and management paradoxes implicit' in international operations. This means that it is important to ensure that in parallel with efforts to enhance the understanding and improve the performance of the global system of local, regional, and national systems that it is also important for the people making decisions to be involved in the process and feel ownership of its results. Beyond stakeholder participation per se, it is crucial to consider the way and the format by which decision-makers are approached and engaged in the exercise. The same is true when organising the debate on the relevance

[1] In reference to existing and emerging innovation capabilities based on technological (social and technological artefacts and infrastructures) options, visions and value networks.

[2] This was the departure point in designing the first questionnaire in the IMS2020 project as described in Section 3.

[3] Contractor and Lorange [19] define three basic distinctions between formal and informal (international) networks. First, formal ones are more visible among those who collaborate and also to other actors outside. Second, informal ones are based on trust developed through social exchange and often evolve as a consequence of growing awareness of mutual interests, which takes time and resources. Third, informal networks are usually developed by those in the front line or carrying out the daily work, whereas formal networks enter a higher management level and are often institutionalised.

of results. Conducting the investigation this way makes it possible to address multiple levels and dimensions of how foresight processes impact on the innovation systems globally.

The consideration of 'glocal' foresight impacts is close to the concept of 'adaptive foresight coined by Weber [22], and can therefore provide valuable guidance. The latter claims that foresight needs to go beyond the level of a collective process to that of individual actors' strategies. This means that there is a need to combine open participation with closed decision making processes. Moreover, there is also the need to adapt the process and results to changes in the environment. Hence, the ability to keep options open until results can be used effectively (or have become irrelevant) is paramount. The basic idea is to add a process cycle to complement foresight with a phase of 'strategic counselling'. Here the results are translated into policy strategies, thus enabling results to be adapted to different policy making bodies or organisations [23]. Such flexibility can also serve diverse users of foresight results, thus leading to diverse impacts in different regions and conditions.

3. Case: intelligent manufacturing systems (IMS) 2020

IMS2020 was an FP7 project funded by the NMP division of the European Commission within the IMS Framework, conducted by an international consortium of 15 core partners and a large group of supportive members from Europe, Japan, Korea, Switzerland, and the USA. The project engaged participants from these and many other countries.

The main objective was the creation of five research roadmaps towards IMS by the year 2020 and beyond. The innovation roadmaps [24] highlight the main milestones of innovation activities (i.e. research and development, management and policy actions) which are needed to achieve a desired vision. Each roadmap focused on one of five key areas of technology (KATs): (i) sustainable manufacturing, products and services; (ii) energy efficient manufacturing; (iii) key technologies; (iv) standardisation; and (v) innovation, competence development and education. The aim was to identify relevant research topics and the supporting actions needed to shape the future of intelligent manufacturing through international cooperation in each of, and across, these areas. Four scenario snapshots of possible states of the future by 2025 were developed. Based on these the IMS2020 Vision was defined. The final roadmaps were designed towards such Joint Vision.

3.1. State of the art and expectations

To kick-off the project-design together with consortia partners most of the initial debate centred on methodological aspects. The JRC-IPTS presented a framework for the initial discussions in order to shape the key questions to be addressed (Fig. 1) and alternative ways to answer these. The approach proposed combined wide participation through online surveys and a wiki platform in combination with interviews and workshops with selected industry experts, as well as the use of

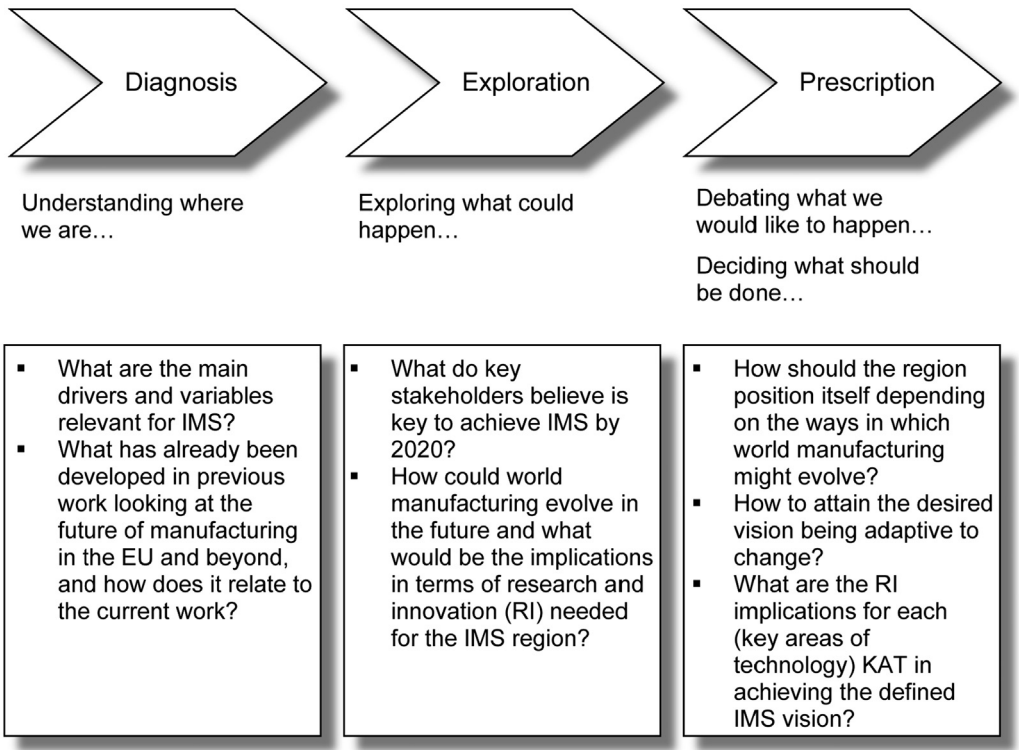

Fig. 1. IMS2020 initial framework.

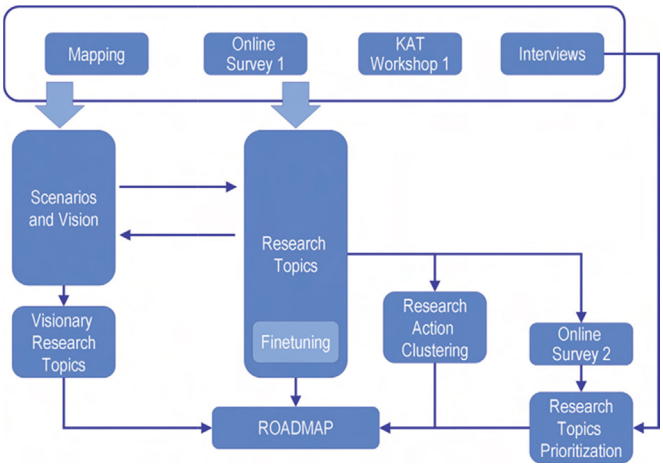

Fig. 2. IMS2020 modular foresight design.

online tools to engage project partners and the supporting road-mapping group[4] in well-defined stages. Such an approach would ensure communication and interaction throughout the project. Also, the idea was to involve the European Commission (client) to debate all milestone results to ensure ownership and commitment, as well as mutual learning so that the process could adapt to needs along the way. In this way the approach proposed would link the strategic goals of the Commission with the operational aspects of the process. It would also ensure that a consensus among project partners and between these and the Commission would emerge along the way.

During the initial discussions many project partners argued that the best way to engage with their informal network of contacts would be through methods other than those initially proposed, such as interviews and smaller workshops. According to the partners the interaction in such smaller events better enables mutual learning and is more effective than collecting information from industry representatives by other means. Therefore, the methodology set up (Fig. 2) for the IMS2020 foresight process was defined in a way that would ensure the highest relevance to inputs coming from the industrial community. At the same time, the design aimed to ensure the international relevance of the results by taking into consideration previous work both at European and International levels as well as seeking the participation of stakeholders from around the globe.

The ultimate design was modular[5] in order to allow for parallel work in panels and to combine different methods for engaging numerous participants in diverse roles and with different contributions. Much of the joint work was conducted using online tools including collaborative platforms like wikipedia, online surveys and video/teleconferences combined with structured interviews and face-to-face meetings. The meetings conducted during crucial phases such as the scenario formulation and the definition of a common vision for the road-mapping work. These created a sufficient basis to continue refinement of the work in online spaces as well as an open wiki platform, thus combining open and collective with closed and expert-driven stages.[6]

In order to understand the state of the art on intelligent and sustainable manufacturing systems, the background work involved the mapping and analysis of (i) scientific literature and of (ii) the main areas covered by twenty worldwide existing roadmaps and thirteen ongoing research projects.

To link findings with stakeholders' expectations, especially those from industry, a first online survey was launched. It identified 261 experts around the globe and a variety of ideas about future innovations linked to one or more KATs and to social, political, industrial, technological, and other changes that could influence the realisation of the proposed idea.

The results from the above initiatives were complemented with the outcomes from two brainstorming workshops and 106 interviews with industry representatives. The latter also asked for innovation ideas for IMS and required changes to have these realised. All these activities produced a total of 754 research issues to be further explored and refined [25].

[4] A large community closely supported the project across its lifespan, with over 350 international participants from 150 industrial organisations.

[5] Könnölä et al. [8] refer to modularity of process design where analogous sub-processes – or modules – can be enacted relatively independently from the other sub-processes. This helps carrying out modules of analogous processes in parallel, for instance in different countries, thereafter further sub-processes can be conducted to interpret these processes, say, from the viewpoint of international priority setting. Sub-processes can thus flexibly accommodate diverse stakeholder interests.

[6] Open and collective stages are those based on processes of collective information gathering, sense making, decision making, dissemination or implementation of results. These are bottom-up approaches that put more stress on interaction. On the other hand, closed and expert-driven stages are those based on top-down approaches that work from a fixed procedure. These are often small panels of experts drawn from different stakeholder groups.

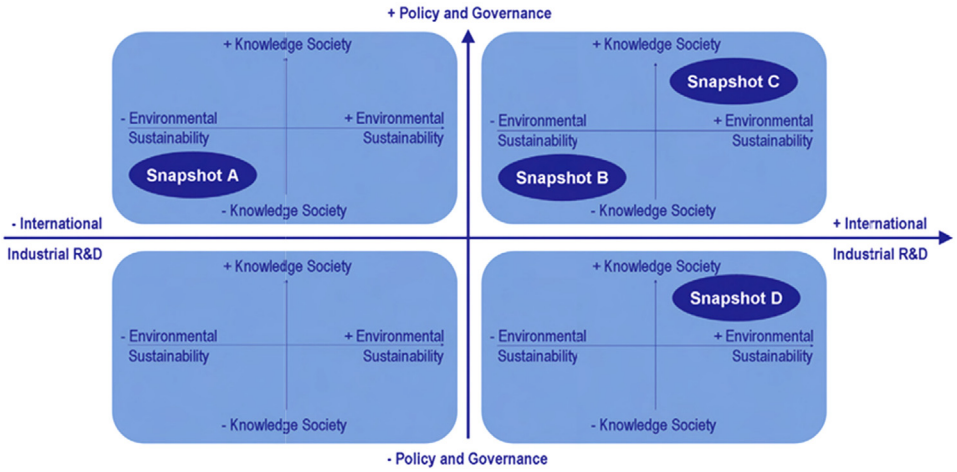

Fig. 3. IMS2020 scenarios.

3.2. Scenarios and joint vision

A more in-depth analysis of the findings of the state of the art and expectations was undertaken for all five KATs. The results were the basis for the selection of the variables used to develop the scenarios within the IMS2020 project. Moreover, the first online questionnaire and interviews with key industry actors took into account those research topics already mapped so that new topics would be identified.

The scenario work was devised and coordinated by JRC-IPTS. Project partners were engaged throughout this activity with support from JRC-IPTS. The methodology employed consisted of nine main phases:

1. Mapping activity to identify and refine KAT dimensions, but most importantly to scan dimensions used in previous scenario and roadmapping projects;
2. Linking the findings of previous projects and research with the results of the mapping, the interviews and the first online survey. The compiled results were discussed in a workshop with all project partners to select the main impact dimensions which influence all the KATs;
3. Defining the main features of all identified variables and their possible behaviours related to the selected main impact dimensions;
4. Devising a framework, according to Fig. 3 (below), based on the main impact dimensions which were used to select the snapshots to be developed. The selected main impact dimensions were: (i) policy and governance, (ii) international industrial R&D, (iii) knowledge society and (iv) environmental sustainability;
5. Positioning the scenario snapshots within the defined framework. At first, JRC-IPTS proposed that the snapshots to be developed should be those at the corner of each quadrant. However, all 16 possible snapshots were discussed in a workshop with all project partners' who jointly decided to position snapshots A to D to be developed according to Fig. 3;
6. Developing the selected snapshots highlighting how their main features interact within each possible state of the future by 2025. This work was undertaken mainly using online tools. The timeframe 2025 was selected both to break from current mindsets and to allow partners to think freely without trying to connect these possible states of the future with the desired IMS2020 vision, which would be developed a step further. This step entailed therefore:

(i) The definition of the main characteristics or behaviours of each snapshot feature;
(ii) The development of a storyline explaining the interactions between these features;

7. Assessing the developed snapshots. For each snapshot feature project partners had to evaluate both the desirability and the likelihood of having such behaviour in 2020. This was done in a dedicated workshop;
8. Discussing the above findings in a vision building workshop to define the main characteristics or behaviours that should constitute the IMS2020 vision;
9. Circulating both the developed snapshots and the IMS2020 vision to all project partners and the road-mapping support group for final refinements and to ensure that it encompasses all IMS regions.

JRC-IPTS coordinated the entire process and supported four groups that involved all project partners in developing the four snapshots. During a period of a month and a half a number of online tools were used for this process. Tools included MS groove[7] for sharing and updating files and documents, email, virtual room for videoconference and joint work, among others.

[7] Microsoft SharePoint Workspace is a desktop application designed for document collaboration in teams with members who are regularly off-line or who do not share the same network security clearance.

After the snapshots were developed within each of the four groups they were circulated to all project partners and IMS regions for refinements. This was critical to ensure that the developed snapshots would take into consideration not only a European perspective, but also an international one.

In a second stage and after approval of the defined scenario snapshots by all project partners and IMS regions, including the road-mapping support group, project partners had to assess all features within each snapshot scenario with respect to the likelihood and desirability of these becoming reality by 2020. A Likert scale of 1 to 3 was used for this exercise, 1 being not desirable or not likely, and 3 being desirable or likely to happen by 2020. The results of this exercise were then used as an input for the development of the IMS2020 Vision during a vision building workshop, and special attention was given in the discussion to those features which were desired (desirability = 3) and somewhat likely to happen by 2020 (likelihood > 2).

Based on the results of the vision building workshop a first draft of the IMS2020 Vision was developed by JRC-IPTS. Later it was circulated for refinements and to ensure it would capture the views from all project partners and IMS regions.

The final IMS2020 Joint Vision is based on inputs from the mapping activity, the first online survey, industrial workshops, and interviews with industry representatives. It can be summarised into three main statements [26]:

1. Rapid and adaptive user-centred manufacturing, which leads to customised and 'eternal' life cycle solutions.
2. Highly flexible and self-organising value chains, which enable different ways of organising production systems, including infrastructures, and which reduce the time between engaging with end users and delivering a solution.

Sustainable manufacturing possible due to cultural change of individuals and corporations supported by the enforcement of rules and a regulatory framework co-designed between governments, industries and societies.

3.3. Roadmaps

The final IMS2020 Joint Vision comprise a set of around eighty research topics which have been judged to be instrumental for the realisation of the defined vision [25]. These topics have been shared and fine-tuned with the input of experts around the world, including the road-mapping support group, through an online wiki that had over 2500 visits.

The refined research topics were then prioritised in terms of (i) a timeline between 2010 and 2020, (ii) inter-dependencies between research topics (those which would depend on other research topics), and (iii) interest of different IMS regions to participate into collaborative research projects per research topic. The latter took place through a second online survey that counted 359 participants.

The roadmaps have been adapted for use by the European Commission. These start from the implementation of the identified research topics and supporting actions between 2011 and 2013, and show the possible impacts or benefits that they could deliver in a timeline towards the IMS2020 Joint Vision (see Fig. 4 below).

The roadmaps were debated and refined with the European Commission, who was the client of the project and responsible to act upon its results by developing and mobilising the necessary resources. Based on this, the roadmaps were shaped around: (i) research topics (RTs in Fig. 4) which act as 'bricks' with short term implementation needed (starting in

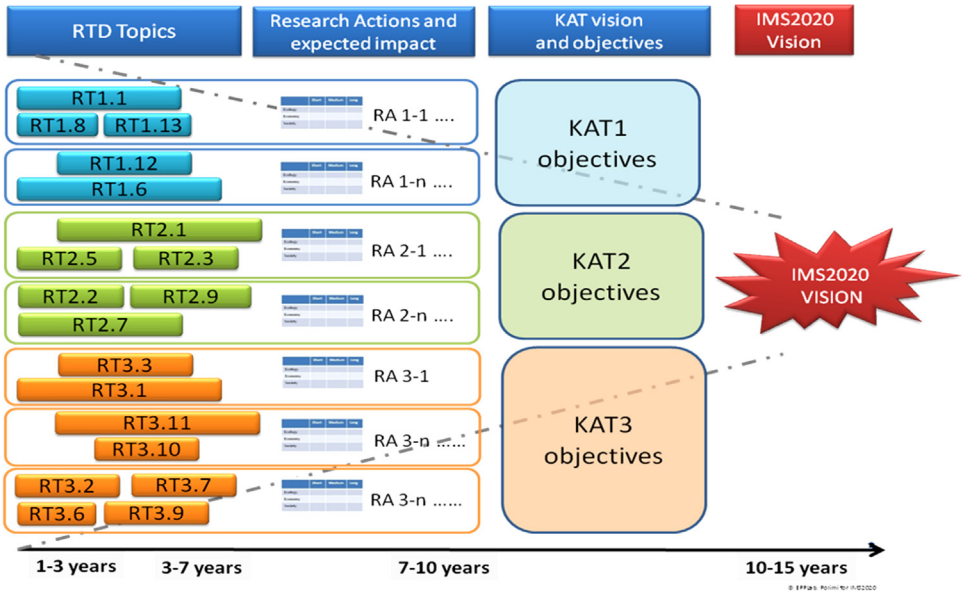

Fig. 4. IMS2020 roadmaps.

1–3 years and to be concluded in 3–7 years); and (ii) actions (RAs in Fig. 4) that are of mid-term implementation (7–10 years), with a wider focus and linked to the research topics, but equally important in attaining the IMS2020 Vision. To support shaping and refining robust and attainable RTs and RAs the IMS2020 Vision was translated into SMART (i.e. Specific, Measurable, Achievable, Realistic and Timely) objectives for each KAT.[8]

3.4. Results and dissemination

One of the main strengths of the project stemmed from the amount of support and industry involvement it achieved, as well as the political momentum and support it generated. It developed a fruitful collaboration between public bodies, policy makers and companies.

The devised Joint Vision and roadmaps, which include the milestones of innovation activities identified, was open for wide consultation in the IMS region and beyond through a wiki platform. Final results were presented in the form of roadmaps between today and 2020 to enable the European Commission to identify and select research priorities to be funded in collaboration with the IMS region in this timeline. Results are currently being used to develop further framework programme (FP) 7 calls and in shaping future RI calls from 2014. However, it may be far more relevant how the whole process created a systemic understanding and a common vision amongst the stakeholders taking part in the exercise. This generated momentum for shaping globally the intelligent manufacturing industry of the future [27].

At the same time, new schemes and frameworks to support manufacturing systems research are being developed. These are intended to stimulate small and medium enterprises (SMEs) to participate in international cooperative research and development (R&D) projects.

The project's final result is preparing the ground for new IMS proposals and manufacturing projects as well as establishing international and inter-regional communities. To do so, beyond the close collaborative work with the client, a number of dissemination activities have taken place, most notably: (i) promotion through flyers, the project's website and marketing material distributed in both academic conferences and policy debates; (ii) continuous recruitment of new members comprising both research and industry stakeholders for the Road-mapping Supporting Group, especially outside the existing IMS community, in order to increase the network of stakeholders; and (iii) peer review articles and an edited book.

4. Revisiting the principles for global foresight

The IMS2020 scenario and road-mapping process shed light on some of the challenges that arise when organising global foresight exercises. Table 1 summarises the main lessons learned using four principles that need to be taken into consideration when designing and managing an international foresight exercise.

The proposed framework (Fig. 1) offers guidance across variety of practical dimensions, including: how to link strategic objectives with the operational activities to be performed; ways of ensuring engagement by a diversity of stakeholders; how to use communication channels; and which methods are best suited to particular situations. The framework also helps to focus discussions related to the design and implementation of the project by bringing together the identification and discussion of intended impacts with efforts to define each operational step and question related to guiding the process.

Initial efforts to arrive at a systemic understanding of the process, when combined with both open consultations and closed expert-driven analysis, were critical ingredients for arriving at rigorous and robust results. Taking this approach meant that participants' knew what was expected at each phase and how milestone outcomes would feed into the next steps.

The modular foresight design described in Fig. 2 (Section 3) allowed engagement of numerous participants in different roles and with different kinds of contributions. It also enabled the process and results to be adaptable to changes such as evolving client needs (from a list of priorities for research collaboration feeding the framework programme). Finally, it supported the scenario and road-mapping work which had to be adapted in order to closely involve partners during a period of almost two months.

Flexibility was critical to build ownership of results and enable all project partners to have the same understanding of the ways in which the different pieces would fit together into the whole structure of the project. Further lessons learned are presented below according to the four principles which ought to be considered when designing and managing an international foresight exercise.

4.1. Understanding interconnected innovation systems

In the IMS2020 project the understanding of the global system of sub-systems was attained by mapping scientific literature, patent databases as well as existing research and worldwide roadmaps on manufacturing. The mapping results were brought together with partners' and stakeholders' experience, and shared in internal workshops and weekly Skype

[8] See [25] to check all RTs and RAs for each KAT.

Table 1
Lessons learned.

Activities conducted within IMS 2020	Guiding principles for global foresight			
	Understanding interconnected innovation systems	Responsiveness towards diverse languages and cultures	Capacity to reconfigure international networks	A glocal impact orientation
State-of-the-art and expectations	Analysis of co-patents and co-publications	Use common foresight framework	User of partner contacts and established networks for outreach (survey, interviews, workshops)	Use of common foresight with emphasis on expected impacts
	Literature review	Online survey for the collection of ideas		
Scenarios and joint vision	Multiple scenarios for synthesising drivers inputs in various forms to identify key elements for the joint vision	Multiple approaches to develop scenarios	Online elaboration of scenarios and the vision supported wider engagement	Inclusion of diverse stakeholder interests supporting the definition of the relevant vision
		Inclusion of diverse perspectives in the vision building		
Roadmaps	Stocktaking of the results from other phases	Inclusion of multiple dimensions in roadmapping frame	Intensive online panel work	Cross feeding among different roadmaps to coordinate and target the recommendations
Results and dissemination	Roadmaps and recommendations to address both horizontal and vertical aspects	Informing and engaging stakeholders	Dissemination of results through the networks	Training
		Tailored dissemination to targeted stakeholders		Dissemination in different levels of innovation systems

calls, as well as workshops with industry. This enabled the selection of the variables used to jointly develop the scenarios, which also used inputs from the online surveys and the wiki open consultation.

The combination of open and collective with closed and expert-driven stages enabled, therefore, partners and main collaborators (i.e. European Commission and road-mapping group) to share a common understanding of the system under analysis. It also allowed all the involved parties to explore likely ways in which it could evolve.

Roadmaps have been developed for the European Commission identifying the key resources (i.e. research areas and research topics) that are expected, according to the selected models, to enable the IMS2020 Vision to become a reality. Ultimately it is hoped that once the findings of this project are put into practice it will help EU manufacturing systems to flourish sustainably.[9]

4.2. Responsiveness towards diverse languages and cultures

The most critical stage during the project was the scenario and vision building. This is because none of the partners beyond JRC-IPTS were acquainted with foresight and the alternative processes for building scenarios, joint visions and roadmaps. In order to properly manage this situation, a range of channels were used to engage a diverse set of stakeholders around the world, as outlined in Section 3. Additionally, JRC-IPTS had to provide background explanations of such processes and help to shape the exercise in a way that all partners would be involved and share ownership of the results.

The framework[10] used in the initial discussions (Fig. 1) was critical to link the strategic objectives of the project to the operational activities. It was also highly useful in supporting the design of the exercise and in combining different ways of engaging diverse audiences in different phases across both formal and informal partner networks. In this context, the partner meetings were vital to adapt the process to the evolving client's needs and partners' expectations, and to identify participants for the more closed and expert-driven stages of the project.

From the outset the initial design was geared towards taking into account the specificity of context and intentions when identifying guiding questions (i.e. intended impacts and objectives), determining participants (i.e. type and level of stakeholders' participation), and selecting methods for structuring the dialogues.

[9] However, as research topics were defined based on collaboration needs in the IMS region, it would be a natural activity to move a step further in order to outline what resources would need to be mobilised and developed per IMS involved country as well as jointly: this would be an interesting question for future research or a project. Further efforts to develop and inter-relate regional and national level activities, as done in [28], could have been justified in the IMS2020 project to gain more insight on the developments of different systems.

[10] The mentioned framework has been used by JRC-IPTS in a number of projects and has proved useful to kick-off discussions with diverse stakeholders with different or no understanding of foresight.

The use of online tools was important to enable partners to collaborate across the project within dedicated spaces as well as to engage wider participation in the open stages of the project. Moreover, these tools offered major support for efficient and participatory management of the exercise since their use was integral part of its design. Weekly Skype calls were useful to take stock of performed activities and to define who would be responsible for taking action based on a common understanding of what still had to be done and the direction to follow. The meetings were dedicated to the crucial phases such as the scenario formulation and the common definition of the vision for the road-mapping work. These created a sufficient basis to continue refinement of the work in dedicated online spaces and to reach consensus among partners and collaborators.

Although the diversity of stakeholders involved across the exercise and the communication procedures had been clarified to all from the outset, managing interactions, especially between partners, required more attention. For instance, during the scenario building process, further clarification was needed, which required returning to previous discussions, clarifying decisions already taken and, most importantly, showing how elements would fit together within a bigger picture in order to attain the results and impacts intended.

The modular design of the exercise was conducive to accommodating diverse stakeholder expectations. The idea of embedding such modularity was adapted from another international exercise [29] where stakeholder participation was also based on the definition of explicit roles and responsibilities for the different phases of the process. It is imperative that the modules achieve their objectives on time and on budget [30] while being adaptive; otherwise failures in the performance of individual modules may influence other modules adversely. If this happens it may undermine the stakeholders' commitment to the process and the trustworthiness of the exercise at large [8]. Hence, it is important to plan ahead for likely bottlenecks and include some flexibility, including available resources. Also, from the viewpoint of risk management, the presence of interdependencies makes it advisable to provide some flexibility [31,32] in scheduling, even if the process as a whole may then exhibit more inertia.

By considering the above features in the design phase it is easier to manage the process according to plan. In the IMS2020 project such flexibility was obtained by encouraging partners to have smaller meetings embedded whenever workshops, face-to-face meetings or dissemination activities would take place. These could happen either before or after a planned event. To call for such a meeting partners only had to convince others of its relevance. Such flexibility was very important during the scenario and vision building processes. In both cases meetings not initially planned were scheduled with selected partners in order to ensure common understanding, ownership of results and commitment to the way forward. Moreover, parallel group work with support from online tools was embedded in the process allowing the project to be kept within the planned schedule.

4.3. Capacity to reconfigure international networks

Table 2 below outlines how formal and informal networks were used and how stakeholders were selected, engaged and informed of progress and outcomes.

To interact with wider audiences' two online surveys and a wiki platform were used. An online platform was used by all partners to share and work on common documents. Creativity was fostered in both open or collective and close or expert-driven stages of the project. Workshops with industry representatives were shaped in a way that spaces for mutual learning rather than the simple exchange of information would take place. These combined presentations, roundtable discussions and small groups' debates, always brought in different views on the same topic. In the open and collective stages, the results of online surveys, workshop discussions, interviews and partner meetings were used as input. As a result a number of research topics that would have been difficult to capture otherwise were re-shaped and combined in novel ways due to inputs and discussions enabled through a wiki tool.

As mentioned, the scenario and vision building process required considerable behaviour and expectation management. In the first scenario building workshop a discussion of how scenarios could be deployed and the variables to be selected had to take place. Rather than having partners developing scenarios as planned, the first workshop had to be downscaled and

Table 2
Interacting with stakeholders.

Stakeholders	Selection process	Type of network	Methods for engaging and informing
Project partners	Expertise	Formal	Face-to-face meetings, video/teleconference, Groove, email, groupwork
	Volunteering (for specific activities)	Informal	
EU Commission	Client	Formal	Face-to-face meetings, website, dissemination activities
Industry	Different economic sectors representing IMS region, including roadmapping group	Formal	Interviews, mutual learning workshops, online surveys, wiki platform, website, dissemination activities
	Personal contacts and Internet	Informal	Online surveys, wiki platform, website, dissemination activities
Research	Partners' databases	Formal	Online surveys, wiki platform, website, dissemination activities
	Personal contacts and Internet	Informal	

devoted to the joint selection of variables to be used and the snapshots to be developed within a framework which was jointly constructed. In fact, sixteen possible snapshots were briefly discussed so that partners would feel comfortable with those selected for further development (Fig. 3). Since there was only one extra workshop planned for the scenario work, JRC-IPTS proposed a different approach than the one decided at the kick-off meeting: each selected snapshot would be developed by different teams with support from JRC-IPTS. Later these would be shared among partners, and finally among collaborators. The approach worked very well and enabled partners to feel more secure about the work being done and its results. It also enabled the project to be kept within the planned timetable. After all developed scenarios were approved by partners and stakeholders the second planned workshop was devoted to develop a common vision. Here, although JRC-IPTS was facilitating and giving direction to the discussions, it asked project partners to rotate in chairing and steering the discussions. Again this worked very well and partners felt very motivated during the two-day discussions, which was critical to build ownership of results.

4.4. A 'glocal' impact orientation

The management of the exercise integrated discussions on the outcomes of the exercise from the very first project meetings. The objectives of the exercise as well as the expected impacts on industry and policy were also discussed in meetings with the European Commission. During the kick-off meeting the JRC-IPTS framework (Fig. 1) was used to present different alternatives to achieve the intended impacts, as well as to explain how results could be presented to different audiences (policy, industry and research).

In the design of the first online survey it was necessary to explain and convince partners of the benefits of elaborating the survey questions in a way that would enable it to capture future innovation ideas and the ways in which these could be attained. Only after a debate on the nature of innovation and on how to solicit creative future ideas did partners achieve a common understanding and, therefore, a consensus on the questionnaire used for the first online survey. Debate among partners took place through different communication channels: face-to-face meetings and Skype. A final meeting between JRC-IPTS and those responsible for conducting the survey took place to jointly design the questionnaire. The first online survey was also designed to collect information that would be helpful for understanding both future developments and the actions deemed necessary today in order to prepare for the identified challenges. This approach was key to designing a questionnaire able to elicit the innovative ideas that participants thought critical for IMS both globally and locally.

The combination of open and collective (online surveys, wiki) with closed and expert-driven stages (interviews, workshops, meetings) enabled flexibility in the overall process, such as the one mentioned for developing scenarios and a shared vision. As for results, these have been adapted for use by the European Commission and thus feed both new RI calls within FP7 and future EU calls after 2014. At the same time, the way in which the scenarios, the shared vision, and the final roadmaps were presented made it possible for reach out to both the research and industry communities (results have been presented in a number of conferences).

It is important to highlight that an international approach was sought throughout the exercise. The development of scenarios, the vision building process and the final roadmaps included not only expectations, needs and viewpoints from the IMS region, but also from stakeholders around the globe. The second online survey and the wiki platform also enabled different parties to outline RI topics in which they would be willing to collaborate and with whom. Such an approach allowed the consortia to unlock not only global needs for IMS with respect to RI and collaboration. It also enabled an understanding of which RI topics were more important for certain regions and were expected to have a greater impact in terms of sustainable manufacturing [33] and IMS. This understanding of potential needs at the local level which influence IMS at EU and global levels is therefore critical for shaping future customised RI calls for project collaboration and appropriate funding mechanisms.

5. Conclusions

The IMS2020 scenario and road-mapping process shed light on how future global collaborative research and innovation (RI) could encourage sustainable manufacturing. It highlighted some of the challenges in organising global foresight exercises. For instance, the scalable design was crucial for adapting to geographical dispersion and the large number of participants. Also, the responsiveness to stakeholder needs and interests in the course of the exercise was crucial to keep the participants motivated and to collaborate [34] as well as to share the ownership of the outcomes.

The identification of four principles for global foresight design and management, and the ways in which these have been dealt with in practice, show that these need to be addressed collectively. It also shows that it is beneficial to have all these principles embedded in the design of a foresight exercise in order to ensure successful implementation as well as the ownership of the results and follow-through actions.

Finally, the extensive use of online tools in this project shows how it is practical to deliver on the promise of fast and extensive engagement of stakeholders, independent of geographical location. Building on this experience, we conclude that online working tools offer major support for efficient and participatory management of global foresight. This is especially true when the use of such tools is an integral part of the design of the whole exercise – a finding that deserves further research in order to advance the field of future studies.

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