Chapter 2
Technology Strategy

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2.1 Introduction

Industry 4.0 is the systematic digitalization of an organization's processes (maintenance, production or management) in order to collect, store and analyze its data. By exploring new production approaches, Industry 4.0 provides companies with a different economic model driven by new technologies.

The fourth industrial revolution (Industry 4.0) and its derived digital transformation goes beyond intra-organization challenges: optimizing processes, departments and the business ecosystem of a hyper-connected era.

Technology doesn't provide value to a business on its own. Instead, as written in a recent MIT Sloan Management article *"technology's value comes from doing business differently because technology makes it possible*" [1].

The days are over in which enterprises implement digital elements and think of them as solely technologies. These days, enterprises should consider technology implementation as a strategy. Consider Customer Relationship Management (CRM) software as an example. It's easy to think of CRM as a software application or even as a database to merely keep track of a company's interaction with its customers, but in practice it's neither. CRM is actually a business methodology: it organizes, automates and synchronize business processes (sales, marketing, customer service and technical support). CRM brings a layer of intelligence that allows an enterprise to really understand its customers – their situation, their preferences – and then use this to plan and design business strategies. All in all, to leverage the potential of CRM and many other technologies a strategy, set of goals and roadmap of the combination and interaction of all technologies across an enterprise needs to be defined.

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Digital transformation requires innovative approaches regarding cultural, technological, operational and strategic change.

The present chapter focuses on the challenges and the key actions that a company must take into account in order to carry out a successful digital transformation journey towards an intelligent and connected industry.

This chapter clarifies that Industry 4.0 involves the digital transformation of the industry with the integration and digitalization of all the industrial processes that make up the value chain, characterized by its adaptability, flexibility and efficiency that allows to cover customer's needs in the current market.

We will discuss underlying reasons behind the creation of technology roadmaps, and the necessary steps to carry out a diagnosis followed by the generation, prioritization and planning of I4.0 and digital transformation opportunities. Finally, the key steps to go from definition to action once the roadmap is defined.

2.2 The Path towards Digital Transformation

The manufacturing industry is currently witnessing a transformation as it increasingly moves towards Digital Manufacturing – often known as Industry 4.0, smart manufacturing or factory of the future. Most enterprises are responding to this move to some degree, albeit often cautiously. Caught up in day-to-day business operations, many SMEs and large businesses are struggling to understand current and future technology needs, drive business priorities and define technological implementation plans. In most cases, they do not know how to visualize the Industry 4.0 paradigm (which encompasses the inherent digitalisation of production processes) to their specific situation.

Certainly, any digital transformation can be challenging: it needs to be resource efficient, leverage internal capabilities and have employee buy-in. Figure 2.2-1 shows the main restraints to digitalization, identified through a European SMEs survey run by Canon Research.

Figure 2.2-1 What is restraining business transformation [2]?

Nevertheless, SMEs should see I4.0 transformation as an opportunity, as they have a huge advantage in terms of agility – for them it is much easier and faster to change approaches and resources than it is for big businesses struggling with massive infrastructure, large teams and long service contracts with suppliers.

Even if an SME has already made the most important decision of all – to embrace digital transformation – the large amount of investment options available, technologies to rely on, and decisions to make can be overwhelming. How and where to start can be daunting. To guide corporate efforts, technology roadmaps can be a crucial tool to clarify the technological readiness of an organization and help prioritize the right areas to focus on when building a technology strategy. Furthermore, it can also be used to effectively identify, plan and define digital opportunities across areas of the business.

In fact, as the years go by, the business world is leaning more and more towards technology, making it almost impossible for a lot of firms to separate business strategy from technology strategy. Technology provides new ways to create and capture value, as well as revenue. The right combination of information, digital technology, business know-how and physical assets can constitute a competitive advantage in key business model pillars (improve customer relationships, improve products and services offered, create novel revenue streams, increase operations' efficiencies and so forth). Due to the drastic impact technology can have on a company's success it should be considered as **one of the transversal pillars that define** an organizations' unique Business Model as seen in Figure 2.2-2.

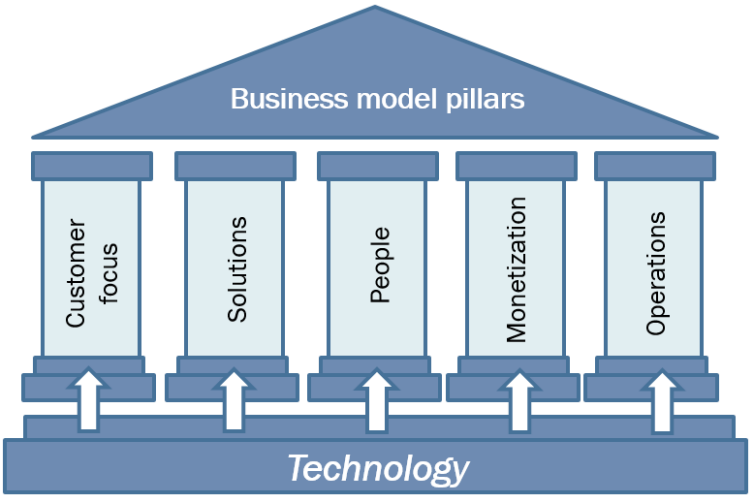

Figure 2.2-2 Technology as part of the business model pillars.

2.2.1 Strategic Roadmapping

Roadmapping is a strategic planning process that helps identify, align and communicate a business need *(Know Why)*, converted into a realistic action plan *(Know What)* and the required underpinning resources *(Know How)* during a specific time span *(Know When).* All of this is summarized in Figure 2.2-3.

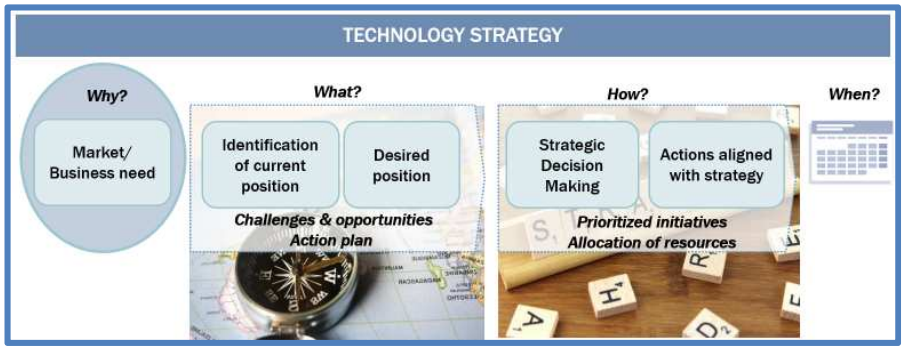

Figure 2.2-3 The four key questions of a technology strategy.

Strategic roadmapping and technology planning as a process was initially developed during the 1970s. Motorola became one of the first companies in the world to develop a formal technology mapping approach. They make use of the roadmap strategy in order to enhance and guide its product developments. On top of that, Motorola used the technology roadmap as a communication tool: to inform and align the needs of its target customers and its workforce with the disruptive novel products to be developed. Around the 1990s it expanded to the electronics and semiconductor industry and since then has exponentially expanded across many other industries.

There are many types of roadmaps that can be used in an organization and selected depending on the end-goal. Some examples include market and strategy roadmaps, knowledge asset planning, product roadmaps and ICT planning. Roadmaps can be presented in a broad range of formats, for example pictorial (flows), text, graphs, tables and bars.

The final roadmap(s) can take many forms, although generally the focus is a graphical representation that provides a top-level strategic view. The process of developing a roadmap is more important than the roadmap itself. The starting point is the future: where your company aims to be. From there you move backwards, defining the initiatives, investments, partnerships and resources that need to be established.

A simplified visual roadmap is depicted in Figure 2.2-4.

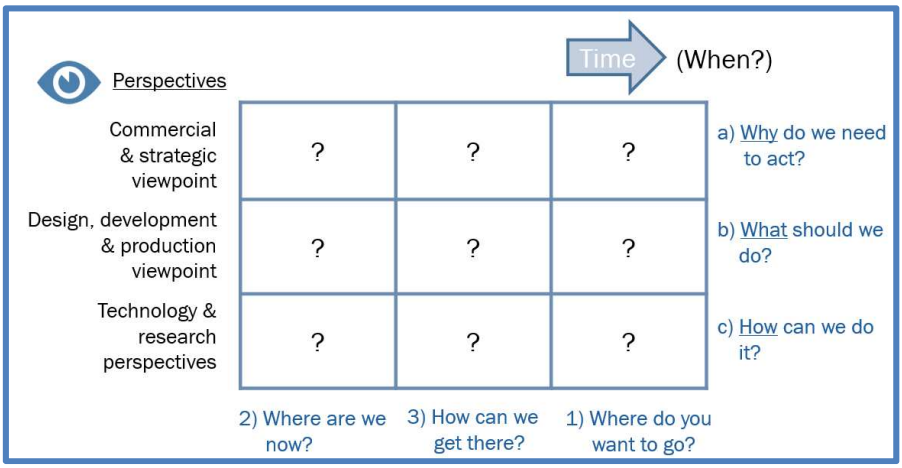

Figure 2.2-4 Simplistic roadmap framework [3].

From all the potential roadmaps, a *technological roadmap* (or digital transformation roadmap) allows you to represent the technology currently available to an organization over a period of time, as well as the best technological options that could be developed or acquired in a specific timespan. In many ways, a technology roadmap can be interpreted as a GPS system for a digital strategy road: it enables businesses to see where they are, where they want to go and how to get there. Therefore, it helps organizations plan which, when, and why certain technologies will be on-boarded while avoiding expensive mistakes and even planning for technologies becoming obsolete.

Some of the key benefits of technology roadmaps are:

- Facilitates the integration of technology into a business.
- Applies to processes, products, customer relationships and asset management.
- Facilitates consensus about needs and the technologies required to satisfy those needs.
- Provides a mechanism to forecast, plan and coordinate technology developments.
- Helps identify new business opportunities and exploit technology.

There are a lot of ways in which a company or industry can create, define and implement a technology roadmap. However, consolidated technology roadmaps share common features. Key considerations when building a technology roadmap are shown in Figure 2.2-5.

ROADMAP CREATION CHECKLIST	
☑	**Identify and prioritize** the business and market needs.
☑	Harvest value as you go, **phase the process** and ensure **early delivery of benefits**. Therefore, include initiatives that generate short-term benefits already in the beginning of the plan (to encourage team motivation when pursuing the other initiatives included in the roadmap).
☑	Ensure **buy-in and support/endorsement from senior management**.
☑	**Allocate resources** (support, time and financial resources).
☑	Pay special focus on the **impact on people** (skills, process, culture and organisational change).
☑	Create the roadmap as a **team activity**, include diverse viewpoints and knowledge to enrich the plan. Process includes a lot of discussion and may need a facilitator.
☑	Keep it **simple and concise**.
☑	**Iterate and learn** from the experience. When developing the initiatives included in the roadmap use critical insights gained over time to modify and make the roadmap even more concise.
☑	Be ready to adjust the roadmap if necessary. The roadmap should be **flexible** and somehow adapted to the constantly changing environment
☑	Make the roadmap **accessible** to all parts of the organisation
☑	**Collaborate with relevant stakeholders**. Leveraging external resources such as consultants can be an effective way to access valuable knowledge and experience, helping you avoid pitfalls and learn from the success of others.

Figure 2.2-5 Roadmap creation checklist.

Moreover, suggested roadmaps should answer 4 key questions:

1. *WHY?*
   It is important to describe the current situation of the company focusing on the dimensions which the roadmap will impact.
   - Analyse company, define
   - Canvas, Pestle, SWOT, technology watch
2. *WHAT?*
   Define the vision and mission of the company and the strategic objectives in order to align the initiatives to implement on the roadmap.
   - Identification of current position and desired position
   - Technology maturity level

3. *HOW?*
   Describe the actions and initiatives to be carried out. These may be technology projects, new business models, organizational changes and modifications to the operational processes, changes to the customer and supplier relations or other activity. Also included the description of technical requirements, costs and execution time, expected results, KPIs, control measures, resourcing, possibility of obtaining financing... These activities will be steps on the critical path. It is also important to describe if these initiatives require a proof of concept or a prototype, and the implications of its scalability.
   - Define initiatives. Create sheets to describe each initiative, prioritization methodologies, define KPIs, create working groups, monitor target attainment
4. *WHEN?*
   Representation of the roadmap in the form of a diagram or schema with the projects or initiatives planned and sequenced over time. The roadmap should include intermediate target states or milestones on the process that the company will achieve ensuring the changing process is on course.
   - Calendarization

The roadmap creation process can help clients understand what threats and opportunities digital might pose to the business and to what degree. It can also help organizations get a better view of where their opportunities and threats are coming from, and what strategy and actions are needed within their organization to build competitive advantage in a quickly evolving digital business environment.

As in any strategy, we need to define the "*what?*". That is our starting point. What is our current situation and where do we want to go when it comes to technology? And then, the "*how?*". What are our strategic priorities and our processes (organizational structure, decision making, incentive systems, and norms and values)?

Although the technological roadmap is a governance document it should be regularly updated as the business evolves. It is a document that should be revised as the external and internal framework of the company changes with new opportunities and challenges that may change the strategy.

2.3 Technology Roadmap Approaches

As previously discussed, methodologies to create digital transformation/ technology roadmaps are very diverse.

Below are 4 summarized examples of different approaches which are taken to develop a digital transformation roadmap.

2.3.1 Partners in Performance

Partners in Performance, a global management consulting firm, proposes an approach that quickly develops a value-centric, prioritised and actionable digital roadmap enabling a company to:

- Identify what customers (and other users, like employees) really value.
- Understand the market and competition, including potential substitutes from outside the industry.
- Apply the right technologies, in the right context.
- Create organisational alignment and set up for execution success.

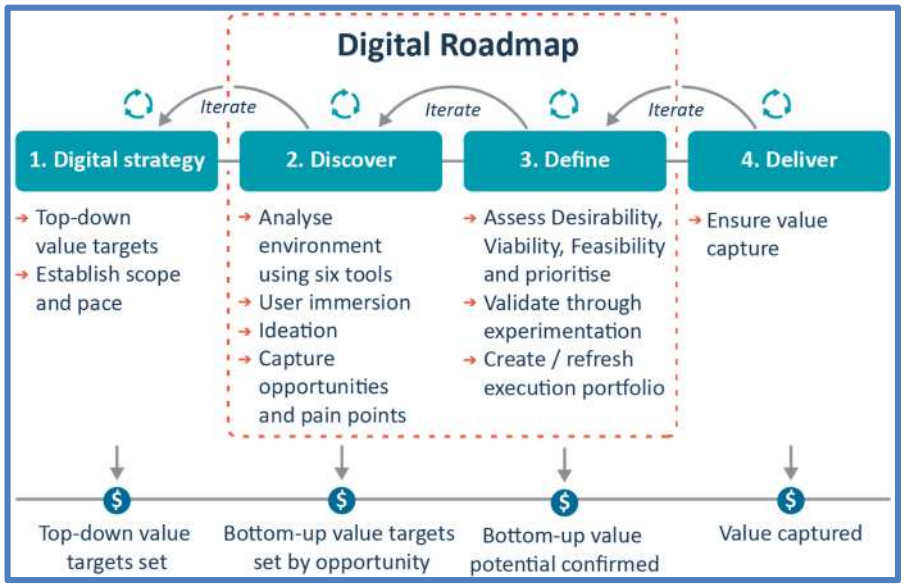

Figure 2.3-1 Partners in Performance proposed roadmap [4].

Further information regarding the Partners in Performance's roadmap methodology can be found at https://www.pip.global/es/services/digital-roadmap

2.3.2 Navvia

Navvia, a company specialised in business process modelling tools, proposes 5 best practices for establishing the digital transformation roadmap:

Figure 2.3-2 Navvia proposed roadmap [5].

1. Define what success looks like for your company.
2. Separate the change into manageable parts.
3. Harvest value as you go, instead of waiting until the end.
4. Focus on the impacts on people (culture, process, skills and organizational change).
5. Adjust course if necessary (the environment is continuously changing).

Further information regarding the Navvia's roadmap methodology can be found at https://navvia.com/digital-transformation-roadmap/

2.3.3 Mckinsey&Company

Mckinsey&Company, a global management consulting firm, proposes 10 guiding principles of a digital transformation divided into 3 principle stages:

1. *Defining value:* Place digital transformation at the core of your agenda. Make significant investments, and set clear, ambitious targets.
2. *Launch and acceleration:* Consider carefully which projects to start with and support them with the necessary resources. Prerequisites include a high-calibre launch team often led by a chief digital officer (CDO), consideration of organizational structure, and the nurturing of a digital culture.
3. *Scaling up:* When the company has a handful of initiatives up and running and starts to capture value, this is also the time to supercharge the transformation and do everything on a bigger scale. The thoughtful sequencing of subsequent initiatives is key to this. In addition, close attention will need to be paid to building more capabilities and eventually an entirely new operating model will be required.

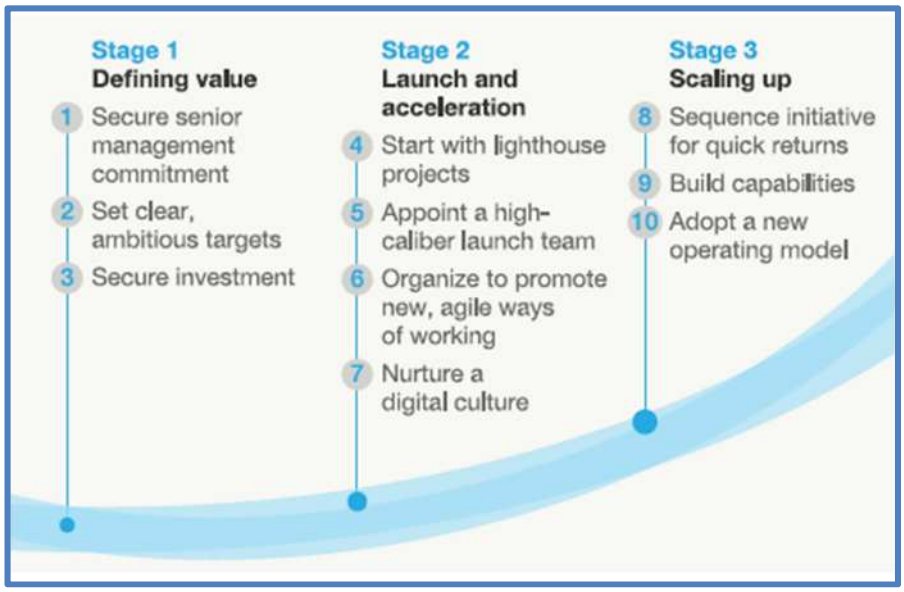

Figure 2.3-3 Ten guiding principles of a digital transformation [6].

Further information regarding the McKinsey's roadmap methodology can be found at https://www.mckinsey.com/industries/financial-services/our-insights/a-roadmap-for-a-digital-transformation

2.3.4 Eurecat

Eurecat, the Technology Centre of Catalonia, has an approach to improve the competitiveness of companies through the development of a transformation plan that allows them to incorporate digitization into their DNA. Defining a new strategy based on the incorporation of new digital technologies that allows the optimization of costs and generation of new business models. Figure 2.3-4 shows the 5 steps:

Figure 2.3-4 Key steps of a technology roadmap.

1. *Diagnosis:* External analysis of technologies and trends in the sector. Internal analysis through face-to-face interviews with the relevant team.
2. *Strategy:* Define the digital vision of the company. Set strategic objectives.

3. *Initiatives:* Generate opportunities and initiatives to boost digitalization for each of the dimensions: products, processes, technology and infrastructure, ecosystem, culture and organization, and information and data.
4. *Planning:* Establish a digital transformation plan minimizing risks and maximizing the impact for the company.
5. *Communication and implementation:* Communicate the company's digital transformation strategy. Sensitize and inspire about digital transformation. Implement the roadmap initiatives.

Further information regarding Eurecat's roadmap methodology can be found at http://smartcatalonia.gencat.cat/web/.content/02_Projectes/documents/SmartCAT_Model-maduresa-I4.0.pdf

2.4 Technology Roadmap Process

In this section further details are presented about the generation process of I4.0/digitalisation opportunities, their prioritization and planning to agree a roadmap that will define the company's strategy.

To illustrate the thinking and exemplify in further details the roadmap sequential methodology the aforementioned I4.0/digital transformation roadmap model developed by EURECAT is presented and described below.

2.4.1 Step 1: Diagnosis

A *diagnosis* is a key tool that allows a company to understand its current status as well as the areas where it should focus its efforts to undertake the digital transformation and progressive path towards I4.0 adoption. Diagnosis can take many forms and outcomes (reports, working groups, interviews, external audits, working sessions, etc). Amongst them, maturity models are a good example of a diagnostic.

Maturity models propose different levels of maturity for different dimensions within the operation of the company. Therefore, these models allow to establish the degree of implementation and development of Industry 4.0 solutions in different business areas, from human resources to IT architectures or production processes.

Several consulting firms and leading market companies have developed digital transformation maturity models. Examples include:

- *PWC Digital Transformation Maturity Model [7]:*
  - Industry 4.0 Capacity Maturity Model.
  - It is based on conclusions derived from a survey of 2,000 participants from leading companies, represented by nine industrial sectors and 26 countries.
  - Key areas that the model analyses include digital business models and customer access, product digitization, integration of value chains, data and

analytics, agile IT architecture, security, legal aspects and taxes, organization, workers and digital culture.

- *Bosch Maturity Model [8]:*
  - Maturity Model of the Internet of Things: How to Succeed in a Connected World.
  - It focuses on planning keys to embrace digital transformation.
  - Key areas that the model analyses include users, companies, things and partners.
- *Rockwell Automation: The Connected Enterprise Maturity Model [9]:*
  - Maturity model of the connected organisation.
  - It focuses on making IT networks more intelligent aiming to improve organisations' capacities and decrease costs. It also includes cultural change management perspectives.
- *PTC (Axeda): Connected Product Maturity Model [10]:*
  - Maturity model of a connected commercial product.
  - Represents the progression of IoT technologies and the progressive return that the company could expect through the expansion of its capabilities.
- *Switzerland Global Enterprise (S-GE): Industry 4.0 Maturity Model [11]:*
  - Industry 4.0 maturity model focused in key success areas.
  - Key areas that the model analyses include products and services, market and customer access, value chain, processes, IT architecture, legal aspects, security, risks and taxes, culture and organization.

Maturity models are represented in levels and areas of action, as shown in the example in Figure 2.4-1. A common feature of the models is that they range from an initial stage, in which a company has a traditional behaviour with very basic use of technologies, to the ideal situation of a fully digitised industrial company, which is able to make the most of I4.0 technologies both for the optimisation of its industrial processes and for the adoption and exploitation of new business models. In this way, a process of evolution is described in which each area must advance. The levels between describe a continuous progression where each subsequent level can be identified by specific criteria and characteristics. It is not necessary for a company to reach the highest level in all areas, each company should define the desired level of progress based on its business strategy.

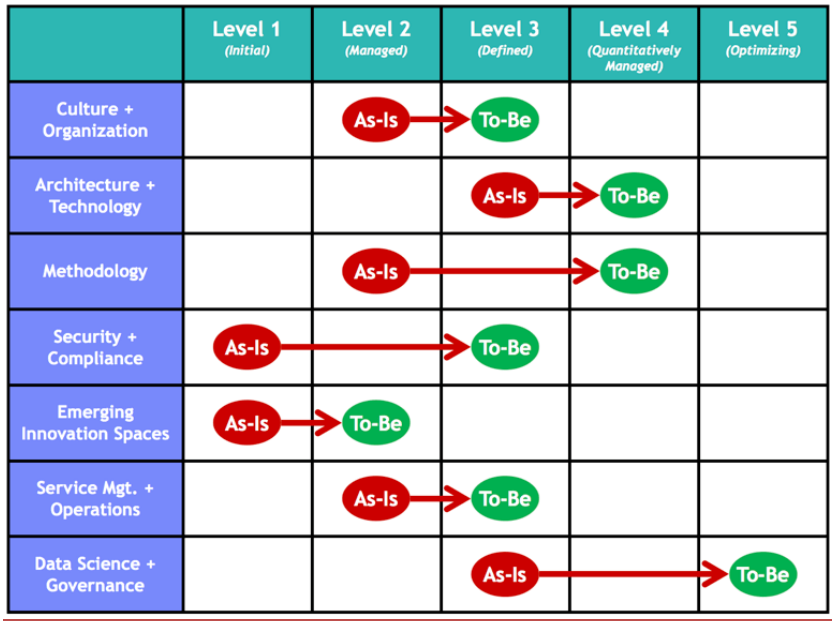

Figure 2.4-1 Simplified capability maturity roadmap (as-is, to-be) [12. Image Rights: IBM.

Following the maturity model created by Eurecat a suggested structure is illustrated in Figure 2.4-2

Maturity Level	Aware 1	Digital Novice 2	Competent 3	Expert 4	Digital leader 5
Products	No digital solutions	Roadmap for smart products	Products with digital solutions. New digital services	New business models	Full customization products. Full Traceability
Productive Processes	No real time Reactive maintenance	Digitalisation roadmap	Pilots of integrated and digitalized production processes Control, planning and KPIs in real time. Traceability	Process optimization (artificial intelligence and cobots) Predictive Maintenance	Autonomous processes. Self-configurable Machines. Prescriptive Maintenance.
Technology and infrastructure	Non-integrated management systems	Production Management Systems (ERP, MES, PLM)	Integrated IoT platform with production and management systems	Recommenders and expert Systems	Simulation technologies and virtual models on plant.
Information And data	Disperse and uncomplete information	Data warehouse roadmap	Centralized knowledge database (Data Warehouse)	Machine learning analytics and techniques	Analysis of external company ecosystem data
Culture And organization	No digitalization strategy	Digital strategy and I4.0 Roadmap	Structure for innovation and digitalization management Coordination IT/OT	Training and more talent on data and I4.0 technologies	Continuous improvement plan
Ecosystem	Without use of digital channels Web 1.0	CRM. Web 2.0. Intranets and extranets.	Digital order management and quality control for providers.	System integration with third-parties.	Integral control and planning of the supply chain Autonomous and predictive management.

Figure 2.4-2 Maturity model on Industry 4.0 [13]. Image rights: Eurecat for Smart Catalonia

This maturity model identifies 5 levels or degrees of adoption of I4.0. These levels range from a minimum (Level 1 – Aware) with an absence of digitization in the organization to a complete integration (Level 5 – Digital Leader) and at different levels of digitization in all processes including decision making supported by data analysis.

The defined maturity levels are:

1. *Aware:* In general, the different functional departments of the company work in isolation and do not have access to integrated information of production and product. In spite of working with sensors, controllers, and monitoring and control systems that allow punctual automation the company does not generate knowledge based on empirical data on the company's productive processes, nor on the products and their associated services, such as maintenance, stock management or supplier management. This lack of knowledge limits the real capacity to take a leap forward and improve productivity, the quality offered, the response to demand, product innovation, or the establishment of new business models with new services, among others. Therefore, the company shows difficulties in satisfying the needs of the customer in the medium and long term with a competitive quality/price ratio with respect to the competition.

2. *Digital Novice:* The company is able to monitor and collect data associated with production processes and/or the performance of its products and/or services in real time. Having this information allows the company to obtain real knowledge (based on data) about its production processes, productivity, quality control and/or the performance of products and/or services. Thanks to this knowledge the company is able to define and implement a first set of indicators (KPIs) for better decision making.

3. *Competent:* The company is able to manage in an integrated way and with certain level of automation the different processes in the plant at the level of production, productivity, quality control and maintenance along with the rest of corporate management systems such as ERP, CRM or PLM. Information integration not only occurs at the factory level, but also at the product level. Thanks to this, the company enables and offers advanced solutions for automated management and control of the product for the customer.

4. *Expert:* The company implements improvement in automated processes. It is capable of optimizing processes, introducing certain intelligence through the generation of new knowledge thanks to the treatment of the information and data collected. This translates into greater efficiency and productivity, a higher quality product (e.g. a large reduction in the number of defective products per batch) and the satisfaction of the customer's needs. In short, it results in greater competitiveness.

5. *Digital Leader:* The company implements continuous improvement to continue advancing both the concept of the intelligent factory and intelligent product. The company is part of an ecosystem integrated with its partners and suppliers that gives it the option to compete at a much higher level, which otherwise would not be possible. The company is able to exploit the valuable information and knowledge gained as a result of its business through new business models.

This higher level (Digital Leader) results in what is known as the smart factory and represents the leap forward to a fully connected and flexible system which signifies the opportunity to drive greater value both within the four walls of the factory and across the supply network. This ideal level of digitization is described as a flexible system that can self-optimize performance across a broader network, self-adapt to and learn from new conditions in real or near-real time, and autonomously run entire production processes [14]. It is important to note that few companies are currently operating at this level.

At the same time, the I4.0 maturity model developed by Eurecat includes 6 areas of action or dimensions within the company in which it will be necessary to take measures to carry out the adoption of I4.0:

1. *Products, Services and New Business Models:* Creating products in a connected industry is different from traditional industry. Industry 4.0 provides the necessary tools to modify the product generated according to changes in demand, both in terms of volume and variability. There is a shift from product-centred production to customer-centred production. Added to this is the possibility of generating new services based on data and information and the use of technologies, which represent great added value for the customer.

2. *Productive Processes:* Activities performed on a recurring basis in business activities. In the case of industry, these include, among others, design, production, quality control, monitoring and stock control. Implementing the automation and digitalization of processes will allow a global vision of the entire value chain, maximizing efficiency and flexibility by producing more and better in less time.

3. *Technology and Infrastructure:* Transformation into Industry 4.0 requires a broad set of digital infrastructures. These infrastructures include:
   - *Software elements:* data processing systems; platforms for integrating the company's processes (customers, stocks, orders, energy expenditure, production time and efficiency), etc.
   - *Hardware elements:* sensors, PLCs, encoders, etc., which provide connectivity to the different machines and equipment in order to capture, store, monitor and analyse the information generated.

4. *Information and Data:* Data is the key to control, management and decision making in Industry 4.0. For this reason, companies must understand and manage data as one of their most important assets. Data must be actively and strategically managed throughout the value chain at all stages of its life cycle. Defining and implementing a plan for data collection, storage, analysis, valuation and sharing becomes basic and necessary to the success of the 4.0 industry implementation. At the same time, a balance must be found between the exchange and protection of data, guaranteeing their security at all times.

5. *Culture and Organisation:* Digital transformation requires a change of mentality throughout the company which in turn needs new organizational models in which the involvement of management is key. There is the need to establish new roles that allow the correct implementation of digitization initiatives fully aligned with strategic objectives. Moreover, the digitalisation demands specialization in IT at all levels of the organization. The recruitment of qualified personnel in this field, as well as the promotion of training programs qualification to existing personnel is key in a correct transformation in Industry 4.0.

6. *Ecosystem (Customers, Providers and Partners):* Companies are part of larger structures and value chains, which need the sharing of information and, therefore, the integration of data, processes and management systems with the aim of offering more value, more quality and more efficiency. This constant exchange of data between actors (suppliers, customers…) requires the correct protection. Therefore, it is necessary to establish alliances defining new cooperation frameworks in which all parties can benefit by overcoming possible initial barriers. In addition, it is necessary to take into account the central place that customers and their demands take in the ecosystem.

Thus, the maturity model provides a view across all capabilities, helping a company to prioritize focus areas and improve aligned with its desired outcome and digital ambitions.

To build the maturity model and identify in which level the enterprise is, both in-depth internal and external reflections are valuable.

In-depth internal analysis

An internal analysis is essential to understanding the company's current digital state. It is important to undertake the analysis with as many roles as possible to get the real situation of the company; interviewing only the management team could lead to a misguided perception of reality. Getting insights from the bottom up and the top down across all the dimensions of the company (the 6 areas in the maturity model previously described) will allow a company to identify where technology and organizational transformation is needed most and where investment is required.

A workshop can be a useful method to include representatives from different areas of the company and discuss together the situation of the company, even

reaching an agreement. But the best way to identify the current situation, needs, deficiencies and areas for improvement is through in-depth interviews with those responsible for the different functional areas of the company – personal meetings with the different people involved in the day-to-day activities. Conducting one-on-one interviews will lead to knowing the limitations of each team, the team's information needs, the hours invested in spreadsheets and printed documents, the lack of communication with other units, the lack of IT software in order to be efficient and even solutions and projects in mind but never implemented.

External analysis: technology surveillance

Internal analysis must be complemented with knowledge of the reality of the environment, monitoring the innovations and technological developments taking place, focusing on their business area, and to be aware of the opportunities and threats presented to them.

Monitoring, environmental scanning and technology watch will make the company aware of the trends in the sector, the state of the art of the technology and the changes on the horizon that could have impact. This process favours the implementation of new projects, the success in the generation of new products and the success in the decision making on technologies of interest.

Figure 2.4-3 Benefits of technology surveillance.

A successful technology watch also charts out future strategies based on the insights gathered. To undertake the technology watch there are surveillance tools that help gather data from various sources and managing the large volume of information, categorizing the information into areas of interest to the company so that it can be analysed. Examples of simple surveillance mechanisms can be found in Figure 2.4-4

Search engines

Search engines & meta search engines

www.google.com
www.ixquick.com
www.polymeta.com
www.dogpile.com
www.metacrawler.com
www.biznar.com Deep web Technologies
http://search.creativecommons.org/
www.kwmap.com

Scientific articles search engines

www.mednar.com Deep web Technologies
www.worldwidescience.org
www.uptodate.com

Automation tools

Google tools

- Search trends : https://trends.google.es/trends/
- Tracking and reporting of website traffic: https://analytics.google.com
- Creation of alerts for specific topics: https://www.google.es/alerts#
- Academic and scientific articles: https://scholar.google.es/

Dashboard tools

- Netvibes: https://www.netvibes.com
- Twitter deck: https://tweetdeck.twitter.com/

Databases

Statistics

- EUROSTAT (http://epp.eurostat.ec.europa.eu)
- OECD statistics (http://stats.oecd.org/)
- UNESCO Institute for Statistics (http://www.uis.unesco.org)
- Instituto Nacional de Estadística (http://www.ine.es)

Market studies

- Research and Markets (www.researchandmarkets.com)
- Frost and Sullivan (http://www.frost.com)
- MARKETSandMARKETS (www.marketsandmarkets.com)
- SABI (http://sabi.bvdep.com)

Subscription fees

Databases

Scientific databases

- SciFinder (chemistry) https://scifinder.cas.org/scifinder
- Web of Knowledge www.accesowok.fecyt.es
- Science Direct http://www.sciencedirect.com
- Wiley on line library www.onlinelibrary.wiley.com
- Scoopit www.scoop.it
- Scopus http://www.scopus.fecyt.es
- Nature www.nature.com
- Kompass http://es.kompass.com/

R&D projects

- CORDIS: http://cordis.europa.eu

Databases

Thesis

- Ministerio de Educación: Information about spanish thesis https://www.educacion.gob.es/teseo
- TDX- Doctoral thesis online https://www.tdx.cat

R&D centres

- MIT https://news.mit.edu
- Fraunhoffer https://fraunhofer.de/en/research/Ccurrent-research.html
- Eurecat https://Eurecat.org/en/news

RSS

RSS (Really Simple Syndication)

- What if they do not have a RSS? We need a html-RSS conversor
- Feedity: https://feedity.com/
- Feed43: https://feed43.com/

Netvibes: https://www.netvibes.com/en

Ex:

https://www.fraunhofer.de/en/research/current-research.html

http://www.interempresas.net/Plastico/Articulos/Actualidad/

Figure 2.4-4 Simple surveillance mechanisms.

It is also important to highlight that patents can be a great source of valuable information. Around 95% of the patent applications that have been pursued since 1883 are available in the public domain[†]. To allocate specific resources in analysing patent databases can not only support enterprises analyse its competition and get information about state-of-the-art technologies but also ensure that no monetary resources are spent on already developed R&D. Some studies *(Enric Escorsa, 2015)* point out that each year 50bn€ are spent across the EU undertaking new R&D in developments that are already patented. In fact, 80% of technical information could be properly found in patent databases.

2.4.2 Step 2: Strategy

Complementary to knowing its current digital reality and, in turn, its current level for each dimension in the maturity model, the company must define its ambition and strategy for digital transformation: "*where do you want to go and what are you trying to do?*" When defining the future state to be reached, it is important to bear in mind that the objective is not to reach the maximum level of digitisation and that all levels must not necessarily progress to the same level. Each dimension must progress to the level that matches the digital ambitions and the strategy of the company itself. Tools and techniques including SWOT analysis [15], Porter's Five Forces [16] and Canvas [17], among others are useful to sort and visualize the results obtained in the diagnosis process.

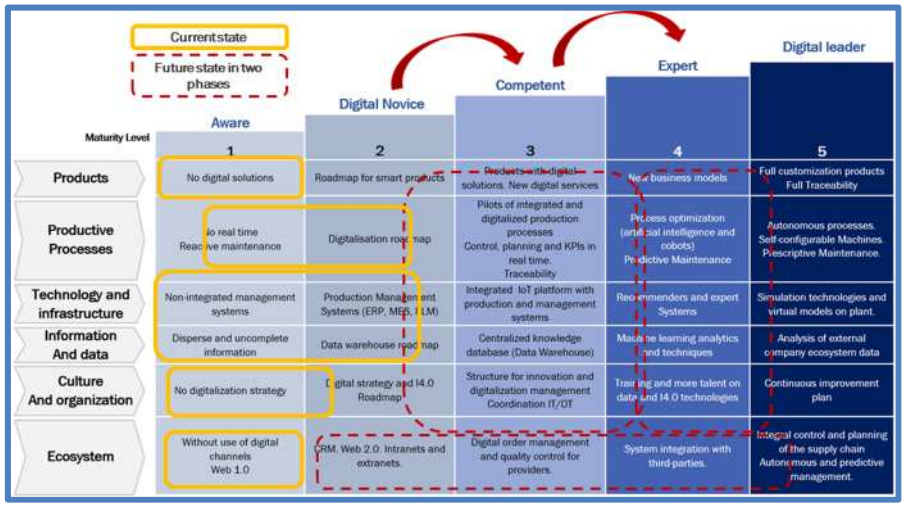

Figure 2.4-5 Maturity Model on Industry 4.0. Current state vs. envisioned state. Example of current and future state definition in the I4.0 adoption maturity model.

[†] James Conley et. al. "Study on Patents and the Public Domain (II)", 2013

Once the present state assessment and future vision definition are completed it becomes possible to identify the systemic gaps. These gaps represent both challenges that need to be addressed and opportunities for digitalisation and improvement.

The identification of opportunities to be developed and the challenges to be addressed will have an impact on different areas of the company in order to achieve the desired level of digitalization. In the Industry 4.0 maturity model presented in Figure 2.4-6 there are 6 dimensions defined when analysing the digitalisation level of an organisation:

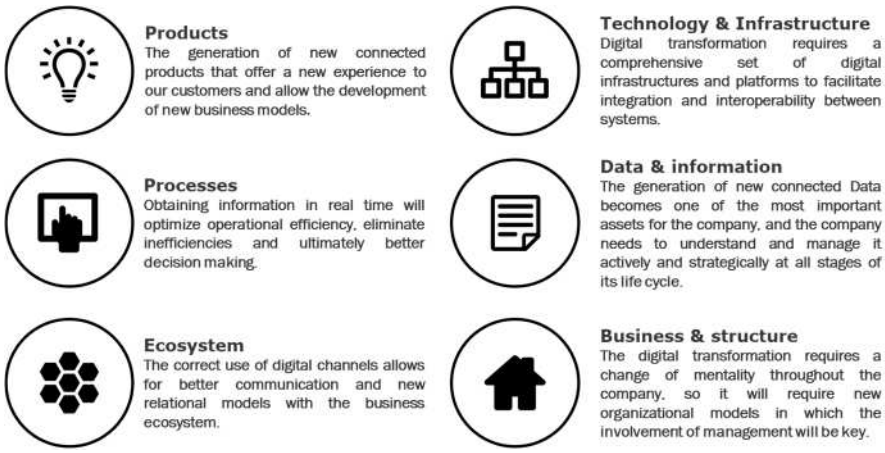

Figure 2.4-6 Six dimensions when analysing the digitalisation level of an organisation.

2.4.3 Step 3: Initiatives

After the challenges and digitalisation opportunities for improvement have been identified, a company can then create initiatives in order to reach the level of digitization desired. In generating and agreeing the initiatives (projects) to be implemented it is important to involve as many heads of departments and team leaders from within the company as possible, in the same way the diagnostics. Generally, this activity will involve several workshops where the result(s) of the diagnostic (maturity model assessment) is presented in a visual way with the current and future desired states the starting point for discussion. From this point the workshop will then work on the different opportunities identified, thus generating the initiatives (projects) the company will implement. Figure 2.4-7 presents some basic examples of digitalisation initiatives for each dimension of the Eurecat maturity model.

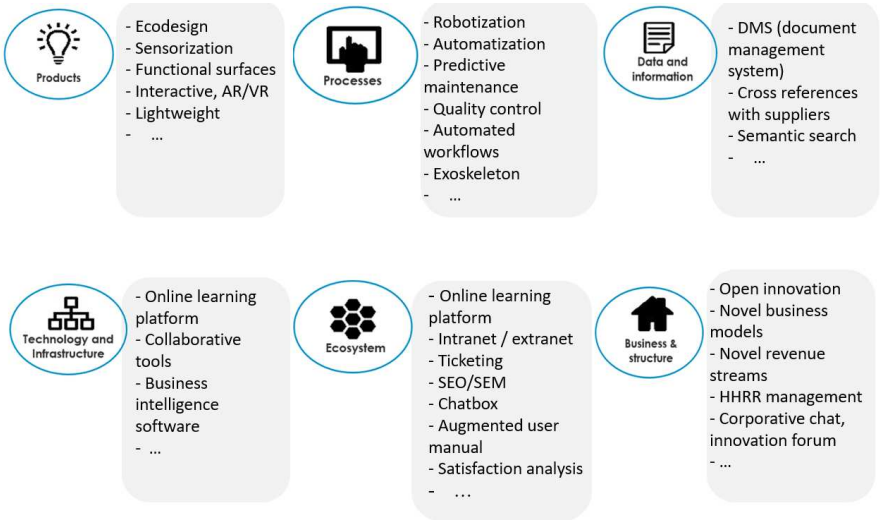

Figure 2.4-7 Examples of digital transformation/ I4.0 initiatives.

For each dimension, several lines of action can be defined. Sample initiatives for digitalisation of core smart factory production processes are illustrated in Figure 2.4-8.

Process	Sample digitalisation Lines of Action
Manufacturing operations	• **Additive manufacturing** to produce rapid prototypes or low-volume spare parts • **Advanced planning and scheduling** using real-time production and inventory data to minimize waste and cycle time • **Cognitive bots and autonomous robots** to effectively execute routine processes at minimal cost with high accuracy • **Digital twin** to digitize an operation and move beyond automation and integration to predictive analyses
Warehouse operations	• **Augmented reality** to assist personnel with pick-and-place tasks • **Autonomous robots** to execute warehouse operations
Inventory tracking	• **Sensors** to track real-time movements and locations of raw materials, work-in-progress and finished goods, and high-value tooling • **Analytics** to optimize inventory on hand and automatically signal for replenishment
Quality	• In-line quality testing using **optical-based analytics** • **Real-time equipment monitoring** to predict potential quality issues
Maintenance	• **Augmented reality** to assist maintenance personnel in maintaining and repairing equipment • **Sensors** on equipment to drive predictive and cognitive maintenance analytics
Environmental, health, and safety	• **Sensors** to geofence dangerous equipment from operating in close proximity to personnel • **Sensors** on personnel to monitor environmental conditions, lack of movement, or other potential threats

Figure 2.4-8 Digitalization initiatives for processes dimension [18].

POTENTIAL LINES OF ACTIONS	
	Ensure comprehensive and scalable data availability in a holistic view.
	Improving information security.
	Optimisation of production and quality control.
	Automation of operations.
	Optimisation of supply planning and internal logistics.
	Improved product development management.
	Improved maintenance management.
	Marketing and sales empowerment.
	Integration with the ecosystem.
	New customer value services.
	Support for HR management, training and change management.
	Optimization efficiency financial administration.
	Adaptation of the organization to the digital transformation.

Figure 2.4-9 Digitalisation opportunities.

Other possible opportunities are also proposed in Figure 2.4-9.

For this workshop it is important to involve experts on technologies in different fields mainly related to the nine technologies commonly defined as key drivers in Industry 4.0. In this way, the inclusion of external consultants, experts in digitalization or people who have participated in similar processes of digital transformation will facilitate the process of generating initiatives. In this way, with the combination of the company's internal knowledge and external expertise in technology and digital transformation, initiatives will be defined to solve the identified opportunities.

For each initiative it is important to define as much is possible its objectives, necessary steps for implementation, estimated costs as well as the expected benefits and risks. One possible way to define the initiatives is through a one-pager definition. This could be defined as a canvas template. Canvas is an easy approach for systematically understanding, designing and starting new projects. It is defined on one page and covers the necessary information for a project definition. It uses neutral language and it is easy to access and understand by all stakeholders of the project.

The most common information elements presented on a canvas for an initiative definition are:

- *Goal:* The main objective of the implementation of the initiative.
- *Description:* Explanation of the initiative. The challenge it intends to solve and how it will be carried out.
- *Benchmark:* Suppliers or solutions identified in order to implement the initiative
- *Planned Actions:* The main steps to carry out the implementation of the initiative.
- *Visual Representation:* Image, diagram or scheme to help understand the initiative.
- *Technology:* The technologies that are necessary to carry out the implementation of the initiative.
- *Estimated Cost:* An estimate of the cost of acquiring and/or implementing the initiative. As detailed as possible. It can also include information on the need for external funding and the time needed to implement it.
- *Benefits:* The main benefits to the company of implementing the initiative. It is important to be able to estimate a payback. This makes it possible to quantify the benefit and facilitates the subsequent prioritization of the initiatives.
- *Risk & Recommendations*: Impediments and problems that may occur during the implementation of the initiative. It also includes dependencies with other initiatives and recommendations for successful implementation.

As an example, Figure 2.4-10 presents the canvas for an initiative of the automatisation of the warehouse through automated guided vehicles.

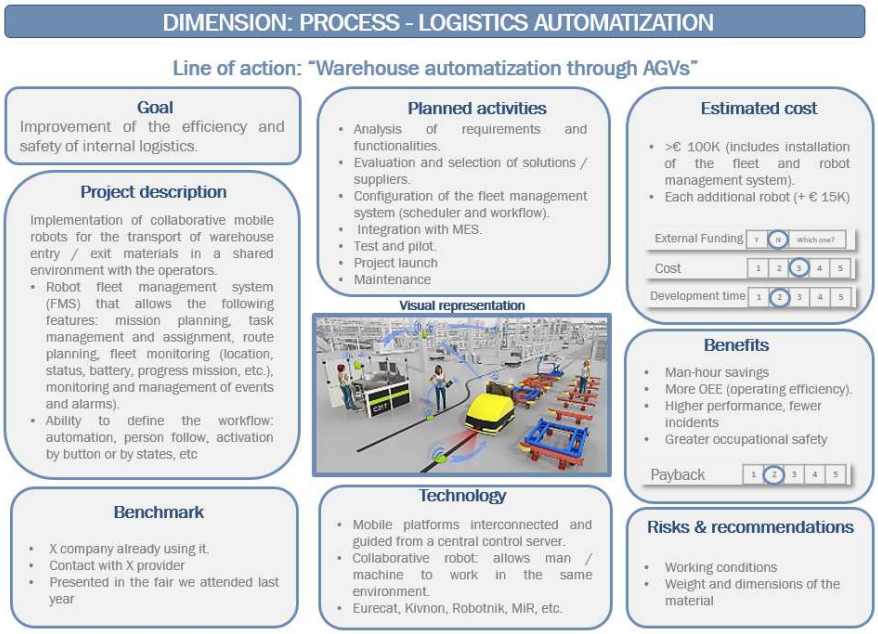

Figure 2.4-10 Canvas project example for Warehouse automatisation through AGVs. Image rights: Eurecat Technology Centre – Consultancy department

2.4.4 Step 4: Planning

Having the map of initiatives is not enough to move to action in terms of digital transformation. The set of initiatives generated must be prioritized, grouped if possible and ultimately sequenced in time to create the digitalisation roadmap for the company in the short, medium and long term. This can be a difficult process because each initiative often has its own business justification and funding. However, it is essential because the roadmap is the guideline and reference to keep the company moving towards its goal.

To prioritise correctly enterprises should select those projects that create maximum impact (e.g. ROI). Notwithstanding, they should also evaluate opportunity costs, dependencies among the initiatives and bundling activities that have synergistic opportunities.

When prioritizing initiatives some criteria that could be taken into account include:

- *Strategic Alignment:* How well the initiative aligns with the business strategy. As most projects will generally claim to align with the digitalisation strategy it is important to define the degree of alignment or even detect if this project would position the company among the best in the sector (top 1, top 3 or top 10) or, on the contrary, it is a commodity that everyone has.
- *Impact or Benefit:* Each initiative generated should have some impact on advancing the company in the process of digital transformation. What is important to evaluate is how far it will move the company forward. Estimating this impact can be related to increased profits, reduced costs or more qualitative elements such as loyalty or sales driver.
- *Cost Estimation:* Knowing the economic cost for the implementation of the initiative is essential to carrying out the prioritization. Economic resources are limited, so the more realistic the estimate can be the more refined can be the prioritization of projects. However, estimating the cost is not an easy task and a company will need to take into account the technologies involved, the workforce, etc.
- *Technology Maturity:* Often, the technology solutions that are required to implement an initiative have been available in the market for several years, with several providers able to supply the technology required. However, it is possible that the technology required is still a beta version in the process of being validated, or has not even been developed. Thus, it is important to identify the maturity of the technology required to implement an initiative – this translates into technological risk involved in carrying out that initiative.

An effective approach to carrying out the prioritisation of all initiatives is to attribute weight factors according to its importance and set levels for each of the evaluation criteria (strategic alignment, impact, cost estimation and technology maturity). And, through a workshop with the designated people, carry out a vote for

each of the initiatives. A visual matrix can be established to facilitate prioritisation and group the initiatives into the following typologies, as shown in Figure 2.4-11.

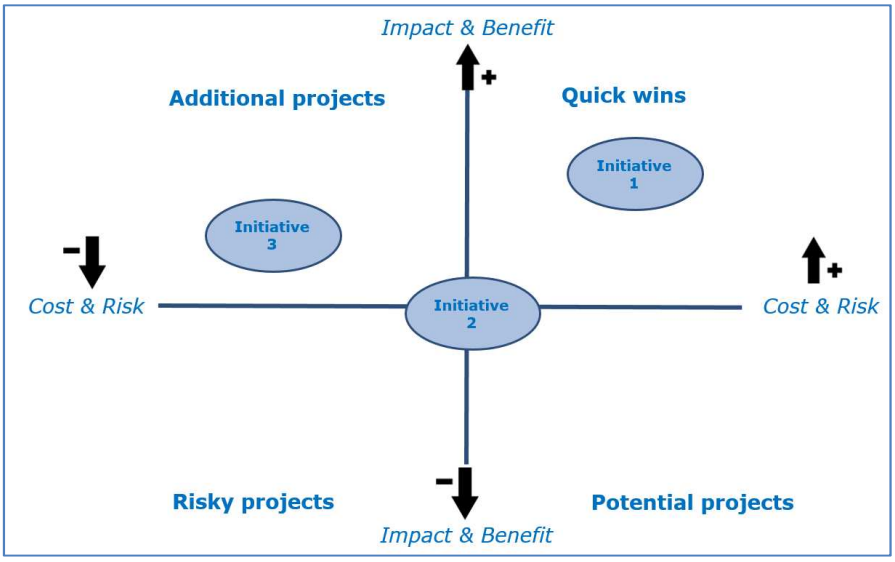

Figure 2.4-11 Example visual matrix to facilitate prioritisation and grouping of initiatives.

This matrix is divided into 4 quadrants:

- *Quick Wins:* Upper right quadrant. Those initiatives that have high impact with low cost and risk. Usually, these are the priority initiatives as they allow results to be achieved early on and gets staff/stakeholders motivated and establishes pace for the whole transformation process.
- *Potential Projects:* Lower right quadrant. Those projects that have a high value impact for the digitalisation of the company but have a higher cost and/or risk associated with them compared to the "quick wins". The degree of strategic alignment may determine an initiatives position in the implementation sequence.
- *Additional Projects:* Upper left quadrant. Those initiatives with a reduced impact in terms of the digitalisation process but have a low risk and cost which make them interesting for implementation in the medium/long term.
- *Risky Projects:* Lower right quadrant. Those projects that due to their low impact in digital transformation and their high cost and risk are discarded in the first instance so as not to waste resources in their implementation.

Ideally the initiatives with high impact and low costs and risks of implementation would be the ones with highest execution priority. However, sometimes is necessary

to take a risk and position the company strategically by betting on a high-impact initiative, despite the high costs or risks involved.

The cost/benefit matrix will result in a first ranking of the initiatives having in the first instance the quick wins followed by the potential projects and ending by the additional projects. However, this arrangement requires an iteration taking into account dependencies between initiatives. That is to say, it is possible that some initiatives cannot be carried out if another initiative has not been implemented previously. For example, when creating an algorithm to predict demand, it is impossible to make the model work if shop data, market data, productivity information, sales values, etc. have not been previously collected. In the same way, if predictive maintenance is to be carried out, it will be impossible without having the machines first connected in a network.

Therefore, taking into account these dependencies, as well as other organizational and structural considerations or financing possibilities, the definitive prioritization of the initiatives to different time horizons will be carried out thus defining the strategy for the digital transformation.

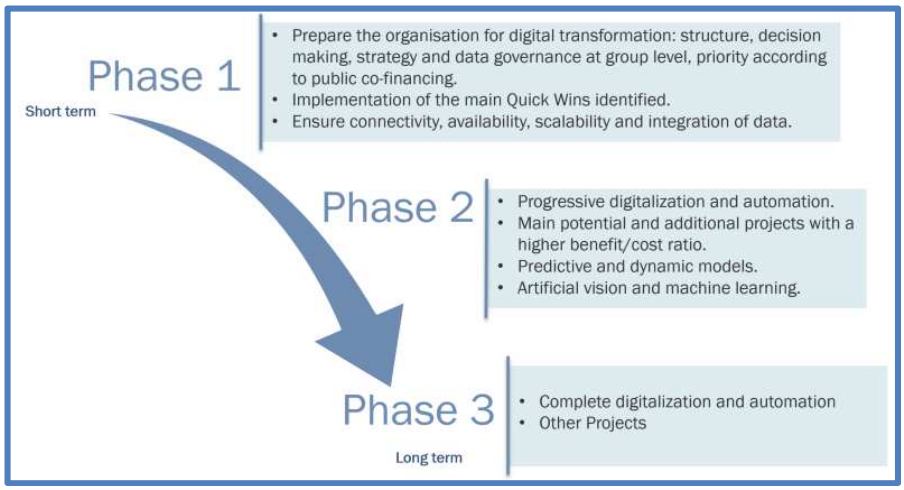

Figure 2.4-12 Roadmap execution time process. Image rights: Eurecat Technology Centre – Consultancy department

As introduced earlier in the chapter, a roadmap can be visually represented in many different ways. Initiatives can be grouped by functional area (production, sales, product development, quality assessment); by key challenges/goals (reducing costs, increasing sales, developing new products or services); or by key strategic themes (International presence, business expansion, higher production capacity, costs reduction). The columns then depict the stages of progression. They can be established by phase; by timing (months, years, quarters); by capability positioning (foundation, competitive, leading); by stage of the strategy (expand product range,

market domination…). There is no right or wrong way to do this, the best way is the one that makes sense for the team. The options are endless, but key is to keep it clear, simple and focused so that all parts of the business can immediatly understand it. Each initiative will have a position in the sequence, being placed under a stage at which it will be implemented and grouped with other initiatives if this is the case. The initiatives may be linked sequentially or plotted in parallel with one or more initiatives. Simplified visual roadmap representations can be found in Figure 2.4-13.

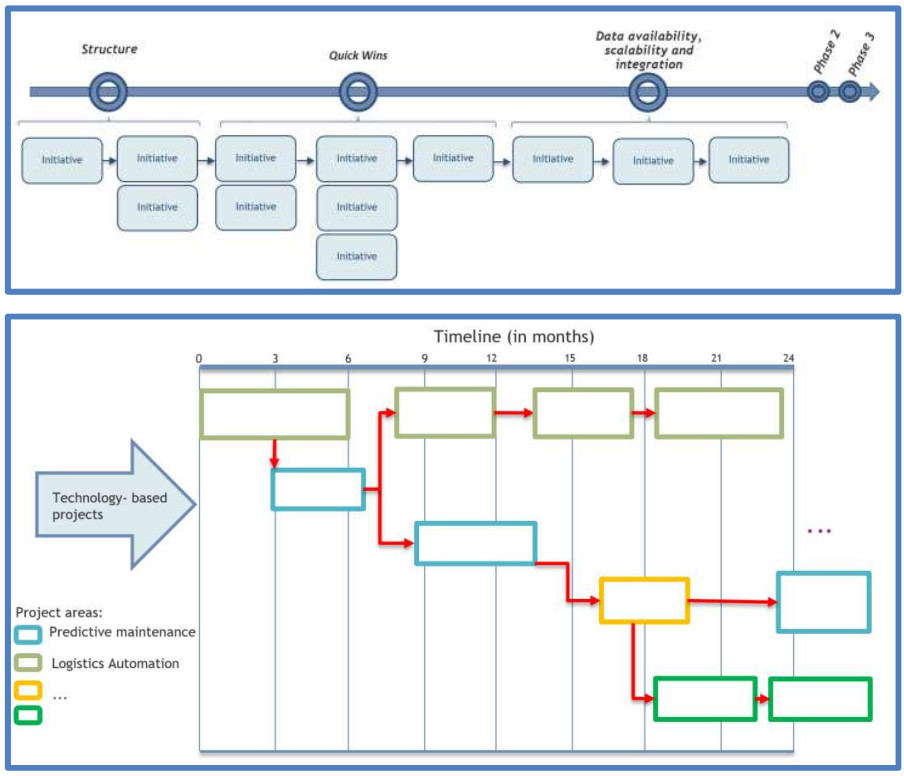

Figure 2.4-13 Roadmap representation examples. Image rights: Eurecat Technology Centre – Consultancy department

When plotting the initiatives it is important to take into account the resources available in terms of people, money and time and the pace that is being set for the company. The answers to some of the following questions will need to be taken into account:

- How many projects can be carried out at the same time?
- Even if I have the funding, do I have the staff to implement it?
- Is the company prepared for the change involved in certain initiatives?

Knowing the reality of the company, its willingness to change and the ability to implement projects will define the final roadmap.

Performing different iterations of the roadmap, with different scenarios to a greater or lesser time horizon can help to define the definitive roadmap.

2.4.5 Step 5: Communication and Implementation

Once the roadmap with the planned digitization strategy has been developed, the time comes for its communication and implementation.

For communication it is recommended that an organisation arrange events, workshops and collecting best practices to inspire your staff, share the common vision and train them on the new tools or technologies.

For the implementation, it is necessary to form a process management team, allocate financial resources (including the creation of a funding/financial plan) and identify appropriate people to implement projects associated with the strategy and make decisions on how to carry them out.

Once the necessary structure is in place to carry out the transformation process, the initiatives proposed in the roadmap must be implemented. Each initiative is a project in its own right and should be treated as such. Therefore, starting from the definition carried out in the roadmap development process, the proposed implementation steps should be followed.

In each case the company must decide how to carry out the implementation. You can acquire technology, develop your own, or collaborate with third parties for the development of it. The decision will have to be made whether to buy, make or collaborate. Although in many projects the decision may seem obvious, in most cases it is not. Each option has its pros and cons so the company must weigh in each case which is the strategy that can provide greater value.

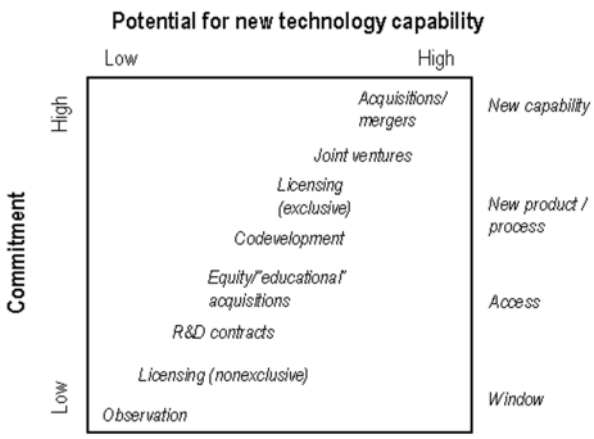

Figure 2.4-14 Matrix for acquisition of technology decision [19]. Source: Mechanism of Technology Sourcing, Leonard-Barton.

Below is a description of each potential strategy:

- *Observation:* Continuous monitoring of competitors' and market approaches on how processes, innovations, products and services are manufactured or offered.
- *Licensing (nonexclusive):* Grants to a third-party (licensee) the right to use the intellectual property, but means that the licensor and any number of other licensees to also exploit the same intellectual property.
- *R&D contracts*: Outsourcing R&D processes to reduce cost and enhance performance. Service agreements could fall within the definition of paid-for R&D.
- *Equity/Educational acquisitions:* Opportunity to investigate a technology in depth through investing, trusting and contributing to foster a venture.
- *Co-development:* To develop some projects, technologies or services jointly with a third-party enterprise. Knowledge "bleed through" from one company to another is inevitably envisaged.
- *Licensing (exclusive):* Gives the highest degree of exclusivity to the licensee. It indeed excludes everyone, even the licensor, from the use of the technology (clauses in the contract can be established to limit this). The licensee firm will enjoy a monopoly position over the use and commercialization of the invention.
- *Joint-Ventures:* Arrangement in which two or more businesses agree to pool their efforts and resources for the purpose of accomplishing a specific task, mainly to create a new business or project.
- *Acquisitions/mergers:* When one company takes over another and clearly establishes itself as the new owner, the purchase is called an acquisition. On the other hand, a merger is when two firms, generally about the same size, agree to go forward as a single new company.

Although each project is different, establishing alliances with technology providers or R&D entities such as technology centres and universities will surely enhance the process and provide support in the execution.

Additionally, when the roadmap is put into action and projects and technological or organisational solutions are implemented, it is essential to monitor progress and ensure that it remains in track. In order to monitor evolution, it is important to define metrics and indicators in order to detect whether the implementation process achieves the desired results and is aligned with the business objectives and strategy.

To create a transformation KPI, Gartner recommends asking these 5 key questions:

1. What is being measured? An example might be the percentage of customer interactions that are virtual/digital.
2. Where are we today?
3. What is our target goal?
4. What is our desired business outcome/benefit? For example, 50% better customer outcomes and 20% lower cost.

5. What is our balance point? (A “balance point” defines the reasons why a company shouldn’t over-digitalize. The law of diminishing returns applies also, and sometimes it makes no sense to have 100% as a goal. For example, a South American company might want to move all of its customers to mobile transactions, but in some countries 100% of consumers use a smartphone, while in other countries only 15% do).

Some examples of general milestones are proposed below:

- Digital proficiency
  - Reach of the organization in the market
  - I4.0 and digital maturity quotient of the employees including board and senior leaders
- Customer focus
  - Net promoter score
  - The rate of new customer acquisition
  - Number of customer touch points addressed to improve customer experience positively
  - Reduction in time to market new products to customers
  - Change in customer behaviour over time across channels
- Return on innovation
  - Percentage of revenue from new products/services introduced
  - Percentage of the profit from new ideas implemented
  - Number of innovative ideas that are effectively implemented
  - Number of new products or services launched in the market
  - Number of new business models adopted for different classes of customers

It should also be borne in mind that the roadmap must be a living document that has to adapt and grow with the company. It must be revised and analyzed frequently to update it in line with changes of the company’s own business requirements, external influence of competitors, customer demands or disruption of new technologies.

In the following chapter we will discuss that the integration of I4.0 and people’s perspectives. Discovering how to understand, reflect, lead, and apply the right tools to manage well people through the Industry 4.0 realm.

2.5 Building a Technology Roadmap: Practical Case Study

As already presented, technology roadmaps can be essential tools for assessing opportunities and defining how we accomplish our I4.0 objectives. It is a statement of intent and direction, coordinating the strategic options for a path to get there.

Technology roadmapping techniques can be used by organisations of all sizes, from SMEs to big corporations. The case study below outlines the range of challenges faced by a specific an SME (Casa Ametller) and how roadmapping has been used to visualise and develop strategies.

2.5.1 Interview with the Innovation Manager at Casa Ametller

How would you describe Casa Ametller?

Casa Ametller is a supermarket chain specialized in fresh products. The company, founded in 2001, opted for a vertical integration strategy: managing the entire value chain from the fields (currently owning more than 1,500 hectares), to the in-house production of food, vegetables and even prepared dishes such as tortillas, soups and creams amongst many others. Through the quality and proximity added value the segment of population that they have captivated the most are citizens interested in a healthy diet that are somehow aware of the ecological impact of the food industry.

The Casa Ametller group has more than 94 stores, a fixed workforce of 2,000 people and a turnover of more than 162 million euros (2017).

The company Ametller Origen Obradors (AOO) is integrated within the Prepared Food Division of the Ametller Group. It produces about 160 product references, highlighting the pre-cooked lines and the dairy line. AOO generated around 12 million euros in revenues, with a workforce of 90 workers.

What factors (external or internal) have been key to consider the need to create a technology roadmap?

The incorporation of technology into any productive processes must be guided, under a general plant strategy and following the objectives set by the company incorporating not only a short-sighted vision but keeping in mind:

1. The impact that a technology can have when creating new products and opening up to new markets,
2. The interaction with other machines, processes and know-how in the present and future.
3. Value the impact new technological projects have as an investment to improve quality, efficiency, productivity and serve more and better the final customer.

With an annual growth of more than 17%, the improvement in efficiency and control of processes is crucial for AOO to be able to respond to the increase in demand in the coming years. In this regards, technology plays a very important role.

Let's explain a specific case faced by Casa Ametller: tortilla flip and the subsequent packing used to be a laborious task that caused frequent wounds to the operators. The recent automation of this task, to be carried out by a machine with more than 30 pans, makes the process almost automatic. The staff have been relocated to process monitoring and controlling tasks – guaranteeing at all times the quality, agility and correct execution of the process. This example is transferable to the rest of the factory. Are there processes where technology can play a key role? Where could novel machinery improve the speed and control that will enable the proper continuity and growth of the company, the welfare of its workers and the quality improvement of the final products? Without a doubt, a technological roadmap is key to guide the identification, definition, prioritization and interrelation of these processes.

Did you find it useful to develop a technological roadmap?

Yes, because it has been possible to visualize the most urgent technological needs for our enterprise without becoming biased and focused only on extinguishing fires in the short term. Allocating time and resources to share points of view between the team and also with moderators and external technological experts has allowed us to have a more global and disruptive vision. Conceptualizing projects also in the medium and long term, prioritizing their place and visualizing the expected impacts and the way forward to achieve a correct implementation.

From the technological roadmap we have extracted the opportunities derived from the technological improvement proposed, identifying a clear and common way to make the current plant more competitive, to know what elements to modify to improve the quality and efficiency of the processes, to set the path towards to the greater standardization of the quality of the products and, in particular, to design small-scale pilots that serve us for the design of the new plant.

What advice would you give to a company that has not yet started the process?

In our case, we would highly recommend using external support that provides methodological expertise on how to create and implement the roadmap itself, as well as providing an overview of what is happening to the market and which technologies could be applicable and most appropriate to our processes.

What are some of the so-called Industry 4.0 technologies that have been included in your roadmap? Can you give an example of a project or specific technology application?

To be able to implement the roadmap several complementary technologies are being considered to be gradually incorporated in order to improve our production efficiency. Some of these technologies are technologies based on the cloud and big data. Another technology is artificial intelligence, specifically techniques based on automatic learning which will help us analyse the data we have in order to detect

patterns and be able to design decision support systems that allow us to optimize certain activities of the production process, such as the daily planning of production orders in the plant. A multitude of variables will be taken into account, such as unscheduled stops due to incidents, or the needs of maintenance actions on the lines and equipment to minimize the number of these unplanned stops.

How do you expect to track the roadmap implementation success?

In order to ensure the correct implementation of the roadmap, technological change will be incorporated into the weekly meetings of the plant team. Resources will be allocated to establish a monitoring committee and execute the specific projects selected. In addition, external consultancy services will be contracted to develop and provide external support to certain projects. Methods to track and record the success of the roadmap specific KPIs are being established.

2.6 Conclusions

This chapter introduced the generation I4.0/digital transformation roadmap. Firstly, we discovered the importance of maturity models in orders to identify the gap between the actual digital state of the company and the desired future vision defined for each dimension of the company. Once the gap is identified, it is possible to generate I4.0 / digitalisation opportunities.

We learned how having an opportunities map it is not enough to implement the digital transformation to be successful. It requires a prioritization process where a cost/benefit matrix helps to get a first ranking dividing the initiatives into quick wins, potential projects, additional projects and risky projects. Setting priorities for different time horizons is essential to align the technology strategy with the business strategy and not overload the resources of the company. Finally, the way to represent the initiatives in the final roadmap was briefly discussed. In this case the representation can take the form that suits best the needs of each organization.

2.7 References

[1] Your Company doesn't need a digital strategy – George Westerman. MIT Sloan Management 2017.
[2] The Digital Transformation Journey: How to modernize your SME. Canon research 2016. Interviews to SME CEOs across the EU.
[3] Albright strategy (Roadmaps and Roadmapping Technology Futures Strategy).
[4] https://www.pip.global/es/services/digital-roadmap
[5] https://navvia.com/digital-transformation-roadmap/
[6] MacKinsey&Company
[7] R.Geissbauer, J.Vedso, I S.Schrauf, 2016, "2016 Global Industry 4.0 Survey", PricewaterhouseCoopers
[8] Febrer 2014, "Capitalizing on the Internet of Things", Bosch, White Paper Series, Part I
[9] Juliol 2014, "The Connected Enterprise Maturity Model", Rockwell Automation, Publication CIE-WP002-EN-P
[10] 2014, "Connected Product Maturity Model", Axeda, white paper
[11] Abril 2016, "INDUSTRY 4.0", Switzerland Global Enterprise, Whitepaper-Opportunities for the Swiss Export Industry
[12] IT maturity level example. IBM Cloud practices. https://www.ibm.com/garage/method/practices/think/it-maturity-model/
[13] Maturity model Industry 4.0. Smart Catalonia
[14] https://www2.deloitte.com/insights/us/en/focus/industry-4-0/smart-factory-connected-manufacturing.html
[15] "SWOT Analysis: Discover New Opportunities, Manage and Eliminate Threats". *www.mindtools.com*. 1006. Retrieved 24 February 2018.
[16] Michael E. Porter, "How Competitive Forces Shape Strategy," May 1979 (Vol. 57, No. 2), pp. 137-145.
[17] Business Model Generation, A. Osterwalder, Yves Pigneur, Alan Smith, and 470 practitioners from 45 countries, self published, 2010
[18] Deloitte University Press. Deloitte Analysis Industry 4.0. Smart Factory https://www2.deloitte.com/insights/us/en/focus/industry--0/smart-factory-connected-manufacturing.html
[19] Leonard-Barton D. 1995. Wellsprings of Knowledge: Building and Sustaining the Sources of Innovation. Harvard Business School Press: Boston, Massachusetts.

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