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Architecting Strategy: Visual Form and Function of Roadmaps

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***Abstract*--Roadmapping is an established management method that supports strategy at innovation, business and sector levels. Roadmaps help to align investments in technology, infrastructure, capabilities and other resources with commercial, organizational and societal goals. The structured visual representation of strategy provided by roadmaps supports dialogue and communication across organizational boundaries. Roadmapping was originally developed for application in large technology-intensive industries such as electronics, aerospace and defense. The underlying principles of the approach are based on systems concepts commonly used to design complex engineered products. However, relatively little research has been undertaken to explore and develop the underlying conceptual basis of the approach, despite growing interest in the academic community, due to the emphasis on its practical origins and application. This paper provides a new perspective on the structure and function of roadmaps, based on well-founded design principles from the discipline of architecture. The conceptual basis of the technique is described, and illustrated with an industrial example, which is then related to perspectives from the field of architecture, strengthening the theoretical foundations of this established method. Based on this cross-disciplinary exploratory study, recommendations for future research are provided.**

I. INTRODUCTION

Motorola is widely credited with the original development of the technology roadmapping approach [43], motivated by the increasing pace of innovation and complexity of technology in the 1970s. The approach was subsequently adopted (and adapted) by other large technology-intensive firms in the electronics, aerospace, defense and other industries [1, 2, 16, 17], and at the sector level [28, 37], owing to the inherent flexibility of the approach, which can be readily customized for different contexts [24, 29].

The core feature of roadmapping is the structured visualization of strategy, to support understanding and communication of complex strategic issues, with this 'lens' acting as a common visual language, as illustrated in Fig. 1 [30]. Roadmapping is a flexible approach for developing and implementing strategy, and has been widely adopted in many strategic contexts and sectors, at innovation, firm and industry levels, as it can address several common challenges:

- The *complex* nature of the industrial, organizational and societal systems.
- The high degree of *uncertainty* associated with long development timeframes.
- *Ambiguity* that arises from the different perspectives needed to address these challenges, which requires involvement of stakeholders from different functions, organizations and sectors.

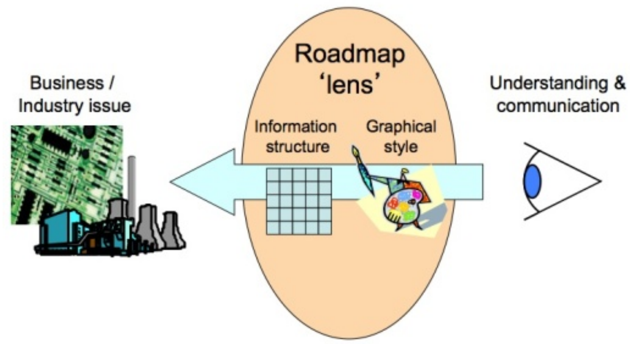

Fig. 1 – Roadmaps as strategic lenses [30]

As indicated in Fig. 1, the roadmapping lens comprises two layers: i) a structural layer, that defines how information is organized in a logical and meaningful way; and ii) a graphical layer, relating to how the information is presented in a way that it can be easily understood and communicated.

Many roadmapping forms exist [3, 18], as illustrated in Fig. 2, which shows 20 specimens extracted from a larger set of 400 for research purposes [30]. Examination of this corpus of roadmaps reveals various types, the most common of which (81% of the sample) includes time as an explicit and critical dimension, which is useful for strategy and planning purposes. The degree of complexity of such roadmaps can vary significantly, in terms of both structure and detail.

Other types of 'roadmaps' identified (17% of the sample) do not have an explicit time dimension, and should not be considered as roadmaps in the classical Motorola-style [43] (the term 'roadmap' is widely used, and 'abused'), but are linked to roadmapping in the sense that they relate to components or stages of the roadmapping process – for example, system and process diagrams. The third type is interesting and diverse in form (representing approximately 2% of the sample), deploying metaphorical representations of strategy – for example, mountains, bridges, metro maps, funnels, trees and board games.

The general and most common roadmapping format is illustrated in Fig. 3 [32], which is derived from its technical and engineering origins in firms such as Motorola [32], Lucent Technologies [2] and Philips [16]. This comprises a time-based multilayer dynamic systems framework, supporting the alignment of strategy within and between organizations [32].

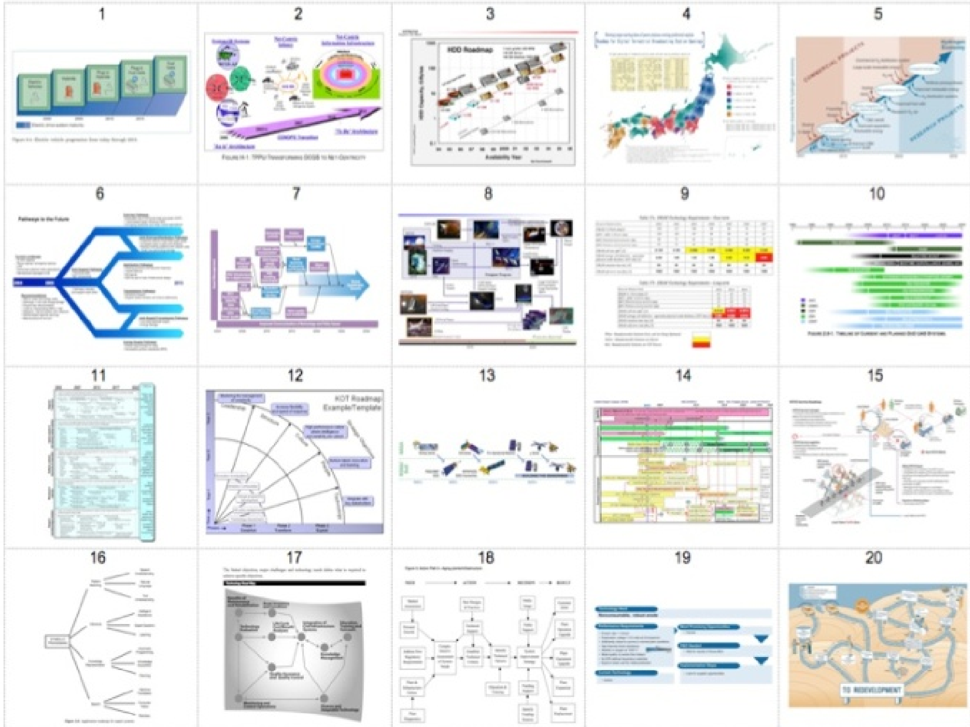

Fig. 2 – Twenty representative graphical roadmap specimens [30]

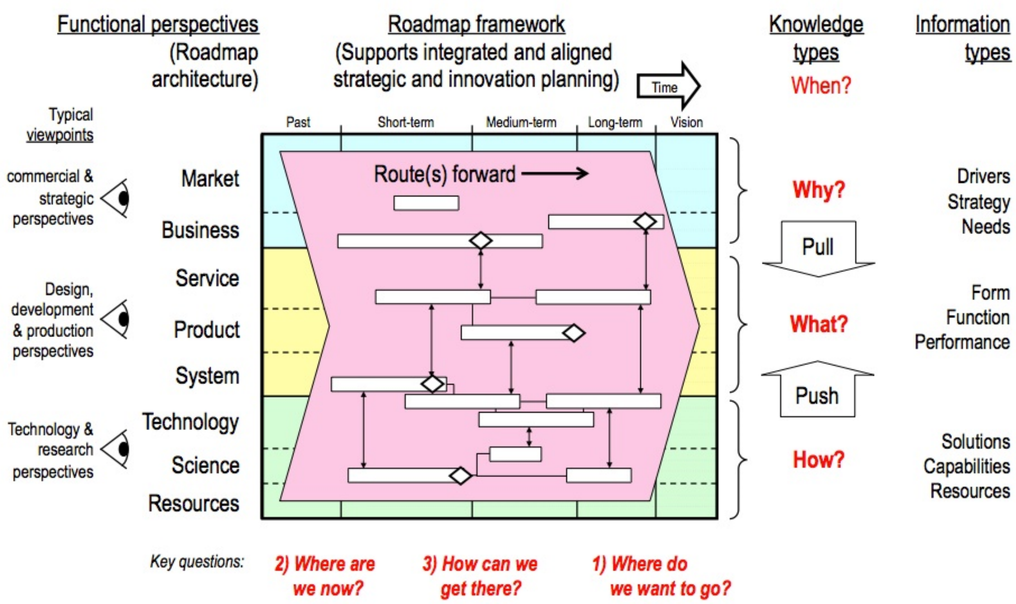

Fig. 3 – Generic time-based multilayer roadmap framework [32]

The format depicted in Fig. 3 provides a systematic framework for the development of strategy, appropriate for program planning, and is generally found to be useful within technical communities. However, this format is not necessarily suitable for communicating strategy to other stakeholders, such as senior management, commercial functions, funding agencies, politicians and the public. Other less complicated formats are appropriate for this purpose, to highlight key strategic objectives, issues and narratives. The deep understanding developed through the use of the systematic roadmap structure shown in Fig. 3 provides a basis for the development of communication roadmaps as a subsequent step, with the most appropriate format depending on the context.

While the systematic roadmapping approach (i.e. Fig. 3) is well understood in practice, and applied widely, there is still a lack of strong theoretical underpinning of the approach. Also, the important visual aspects, which are critical for supporting understanding and communication are not well understood or established. Some efforts have been made (e.g. Blackwell *et al.* [3]), but more research is required if the full potential of the approach is to be achieved.

This paper makes a contribution to this challenge, through the provision of a perspective from a different academic and practical discipline – that of *architecture*, where principles of design and visual expression and communication are well established. This contrasts with the engineering perspective that has dominated the development and application of roadmapping, with its more utilitarian orientation. The authors of this paper are both academics working in the field of technology and innovation management, but with different professional backgrounds. One author has a professional engineering background, and the other practiced for more than a decade as a professional architect. This paper is exploratory in nature, motivated by the potential benefits of bringing together ideas and concepts from these two different disciplines.

In Section II of this paper, the two fundamental types of roadmaps are revisited and illustrated with an illustrative example: i) the standard systematic multilayered format (Fig. 3), and a common simplified format for communication purposes. Section III provides a commentary on these forms from the perspective of the discipline of architecture, building on fundamental principles from that field. Finally, in Section IV, the results of this exploratory study are discussed, conclusions drawn and recommendations made for future research, emphasizing the benefits of cross-disciplinary research.

II. ROADMAPS REVISITED

A simplified version of the general multilayer systematic roadmap structure is presented in Fig. 4, which is comprised of two orthogonal axes:

1. Time is a fundamental dimension, typically represented by the horizontal axis, comprising at least three timeframes: current, intermediate and future states (short, medium and long term). The number and duration of timeframes represented depends on the strategic context – principally the rate of change in the particular context, bounded by the past and future vision.
2. The vertical axes is divided into three broad layers, representing fundamental innovation perspectives (stakeholder views), each of which may be further divided into sub-layers according to an systems-based hierarchical logic, to an appropriate level of granularity, given the focus and scope of the strategic issue/s being addressed.

The ability to adapt both axes of the roadmap structure is the key to its flexibility, as the roadmap framework can be readily adapted to suit virtually any strategic context, at any unit of analysis. Non-linear scales can be used, to allow greater granularity in parts of the roadmap where particular attention is needed. In this way, roadmaps can cover a very broad scope, while also having detailed focus.

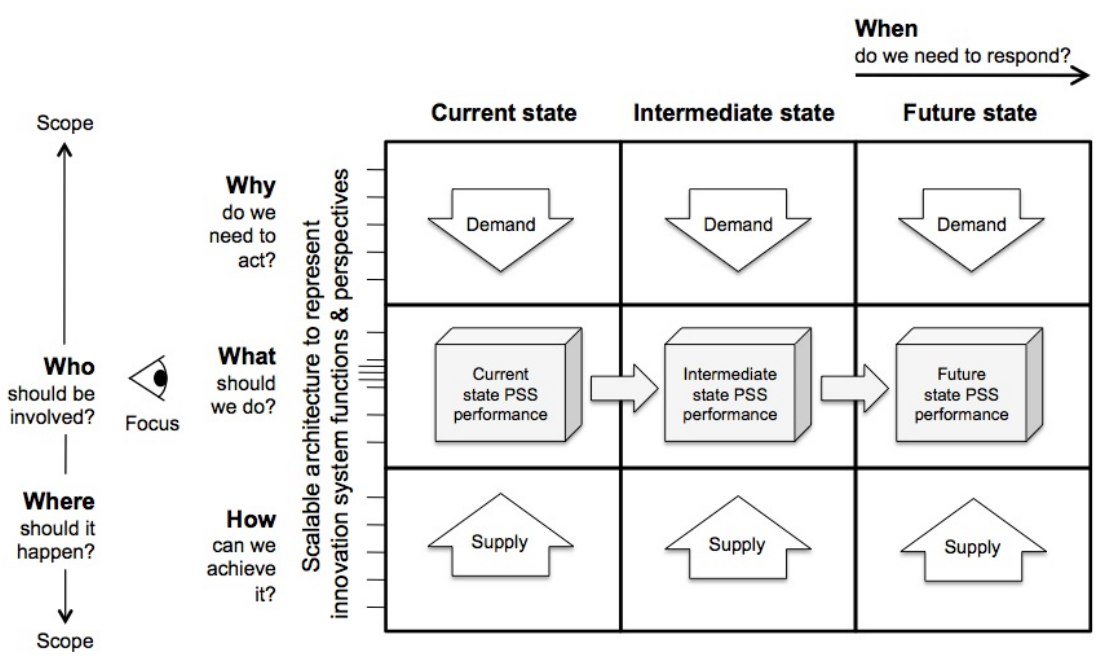

Fig. 4 – Generic time-based multilayer roadmap framework, derived from Fig. 3

The roadmapping framework as described above can be considered as a strategic 'canvas' that can support strategic dialogue and communication, to enable innovation and strategy development and implementation. The evolution of products, services and systems ('PSS') can be explored and depicted, including their required and possible functionality and performance. Typically, other specialized management tools are needed to support this process, such as scenario planning, portfolio management, quality function deployment, and many others [7, 8, 9, 25, 34].

Underpinning the generic roadmap structure (Fig 4) is a 3x3 matrix defined by six fundamental questions that relate to the vertical and horizontal layers of the roadmap.

- *Why* do we need to act?
- *What* should we do?
- *How* can we achieve it?
- *When* do we need to respond?
- *Who* should be involved?
- *Where* should it happen?

To illustrate the application of this generalized roadmapping framework, a simplified historical example is presented in Fig. 5, inspired by the evolution of the camera. Three generations are shown: film-based cameras, digital cameras and cameras embedded in smartphones, over a period of three decades.

The kinds of information types that are relevant to strategy development are shown on the left hand side (vertical axis), including market trends, consumer needs and business strategy; products, services and systems; and technology, finance and skills (these are just examples; the number and type of perspectives included depends on context). These relate to the 'why', 'what' and 'how' questions highlighted in Fig. 4. These themes (layers) are typically associated with different stakeholder perspectives, providing a common language to support dialogue and communication between different functions and organizations, for example marketing, product management and technology, or between customers and suppliers

The strategic development (evolution – i.e. 'when') of cameras, including their functionality and performance, can be mapped within the structure provided by the roadmap framework. This includes both supply- and demand-side drivers that influence the functionality and performance of the camera, with successful innovations being a balance between 'market pull' and 'technology push'.

The three phases of camera evolution shown in Fig. 5 can be summarized as follows:

1. Film-based photography was a major industry for more than 100 years, with Kodak founded in 1888 and eventually controlling 90% of the film and 85% of the camera market in the USA in 1976 [39]. The era of the film camera can be characterized as a period of 'family values', when photographs were taken relatively rarely (compared to today), due to the expense of film and its development, with photographs stored in albums to record and remember key events ('The Kodak moment'). During this era there was fierce competition between Kodak and FujiFilm for market share, with FujiFilm attacking the dominant position of Kodak in the USA on the basis of price [11]. Key technologies at that time were chemistry and optics, with the infrastructure to rapidly process film and deliver photographic prints to customers a key focus.

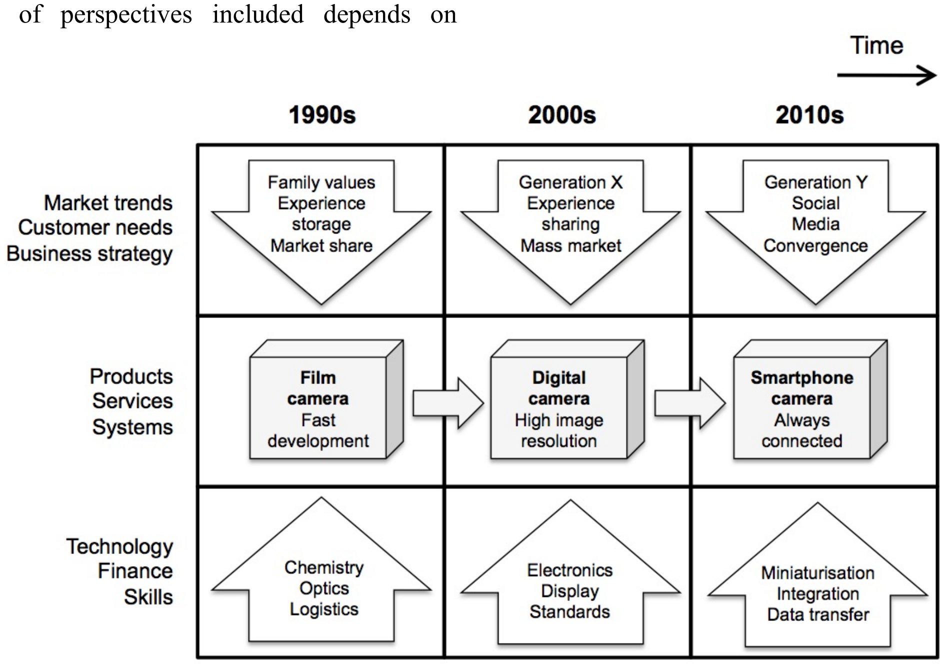

Fig. 5 – Illustrative (historical) example of time-based multilayer roadmap framework, for the evolution of the camera industry

2. In the 2000s (with consumer behavior and needs characterized as ‘Generation X’ [26], digital cameras became dominant (a disruptive technology [6]), displacing film cameras in the market. Kodak did not survive the transition to digital technology, despite having been influential in its development. FujiFilm on the other hand survived, diversifying and exploiting core competences in other markets [23] such as cosmetics [44], supported by its investment in FujiXerox [39]. Complementary technology, such as LCD displays, computer and internet developments allowed the volume of photographs taken to increase by orders of magnitude, and to be shared – immediately through the display function, and with friends and family around the world. Cameras had become electronic products, with new entrants such as Panasonic, Sony and Samsung challenging the traditional camera industry incumbents. The development of jpeg standards for digital images was a key enabler, allowing photographs to be processed, manipulated and shared.
3. As mobile (cell) phones developed, manufacturers started to include additional functionality, including camera technology. Initially the quality was poor, but rapidly improved, with some companies focusing on this aspect as a differentiating function, as part of a convergence trend, so that consumers only had to carry one device. The Apple iPhone became the most popular camera for photographic uploads to the dominant photographic Flickr social media service in 2011 [45], Panasonic launched a Lumix-branded mobile phone in 2012, with a fully integrated Samsung Galaxy camera-smartphone (S4 Zoom) released the same year. The volume of photographs published on social media sites such as Facebook and Twitter has exploded. The consumer behavior and needs in this era is characterized as ‘Generation Y’ [35]. Key technology developments during this period include miniaturization, integration and network development for data transfer (4G, broadband services and wireless networks).

The multilayered roadmap format provides a systematic means for developing strategy, bringing together all of the key stakeholder perspectives needed for successful innovation. However, the resulting roadmaps can be complex (technological innovation is a complex business), and can be difficult to communicate to those not involved in its development. For this purpose simplified formats are needed that can convey key strategic messages and narratives concisely and clearly. There are many such formats, but a popular one is illustrated in Fig. 6 [33], which has the benefit of being closely related in structure to the multilayer systematic format shown in Fig. 4.

The focus of the simplified communication roadmap in Fig. 6 is the product evolution, showing the product generations, highlighting key functional and performance attributes of each product, and how these evolve with time. The product (or more generally PSS) strategy is depicted as a simple linear sequence, arranged as a series of upward steps – a metaphor with positive connotations. Above and below the product strategy the key commercial and technological drivers and challenges are highlighted.

The generic simplified communication roadmap framework shown in Fig. 6 is illustrated with the camera example in Fig. 7. In this case images of the cameras are included to support communication, and key data from the more complete systematic roadmap are displayed, to support communication of the core strategy. The more detailed systematic roadmap can then be used to explain the details behind this simplified depiction, and also for program planning purposes.

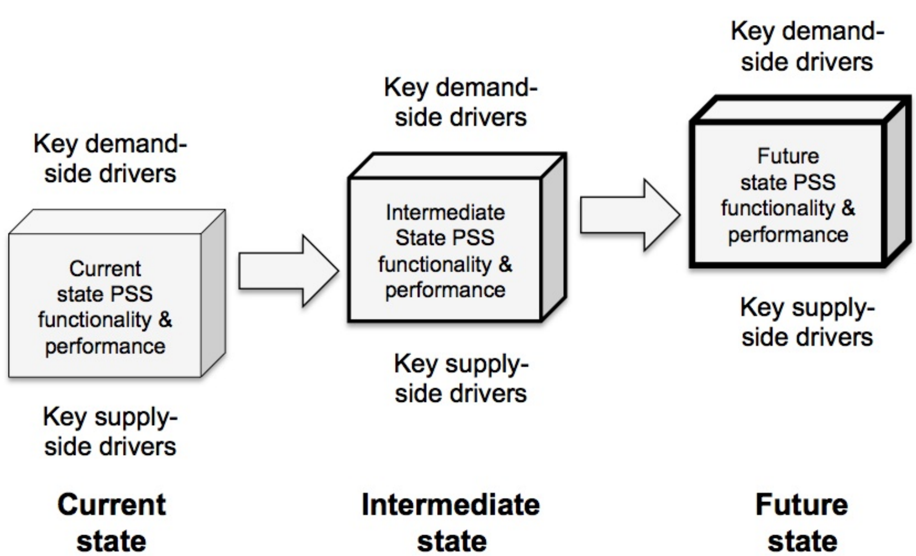

Fig. 6 – Generic simplified communication roadmap framework

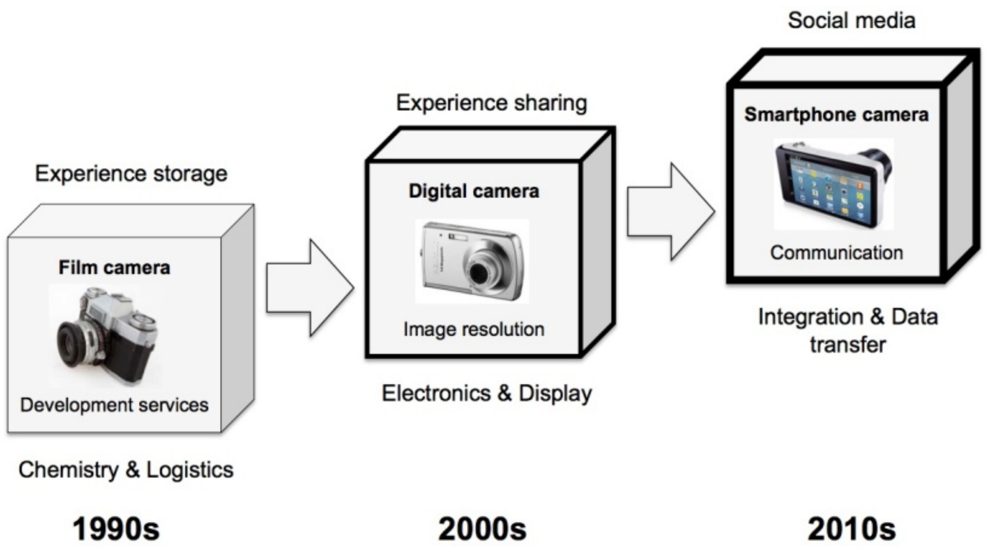

Fig. 7 – Illustrative (historical) example of communication roadmap framework, for camera industry

The design of compelling communication roadmaps is not straightforward, as there are many possible forms, and a number of competences are required, including domain knowledge and graphical design. Research has begun to develop principles and a design process for this [19]. This research is ongoing, but has been piloted successfully several times [20], and is used in training courses, where roadmaps are firstly developed using the multilayer systematic approach, followed by a creative design process to develop communication concept sketches, which would be suitable for guiding the work of a graphic designer. Fig. 8 illustrates such a design sketch from a training workshop in Tokyo in December 2013, which happened to focus on camera technology, using the same format as shown in Fig. 6 & 7.

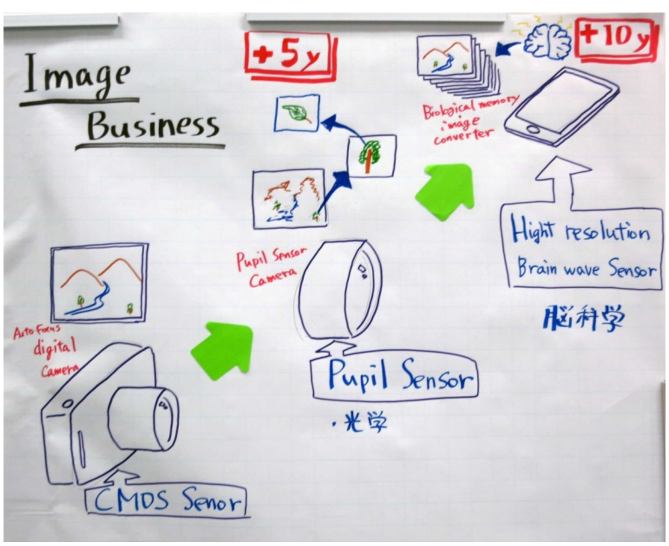

Fig. 8 – Communication roadmap design sketch (courtesy of Yoshimoto Nagahashi, JAIST, 7th December 2013)

III. A PERSPECTIVE FROM THE DISCIPLINE OF ARCHITECTURE

Sections II and III set out the basic principles of roadmapping as method for supporting strategy and innovation, illustrated with a simple retrospective example pertaining to digital cameras. Roadmapping was developed originally, and is most widely applied, technology-intensive firms for supporting the alignment of technology and product strategies, based on systems engineering principles. However, the underlying concepts are purported to be generic [24, 29]. Thus, in this section a different perspective is provided, from the discipline of architecture, which is a mature discipline with a different professional and academic orientation to engineering, but with the similar general goals of designing systems that meet the user needs. It is anticipated that this novel perspective on roadmapping will reinforce certain established roadmapping principles and practices, and challenge others, to strengthen the conceptual foundations and practical utility of the approach.

A. The role of architects and their design process

The built environment is complex, and the discipline of architecture has developed to ensure that the associated social, economic and environmental requirements are addressed appropriately. The resulting artifacts – buildings, can be discussed and compared with other products and services produced by industry. Engineering is involved in the design, development and production all types of products, including buildings, where architects take the lead design and coordination role. For products such as the digital camera described in the previous section, engineers often have a more prominent role, with the development of such products often dominated by functional engineering requirements, with a more utilitarian orientation.

There is clearly a difference between mass produced products such as cameras and large complex one-off projects relating to construction [22]. However, the architect vs. engineering orientation can be seen in such complex product systems too, comparing for example a skyscraper and an oil rig, with the design and coordination lead provided by architects for the former, and engineers for the later. In the following paragraphs the role of architects in the construction industry is briefly presented, before highlighting a few key perspectives for discussion in relation to the engineering-oriented roadmapping approach and example described in Section II.

The elements of every aspect of architecture are complicated. There are many stakeholders involved in construction projects, such as architects, structural designers and engineers, landscape architects, interior designers, electrical and mechanical engineers, and every role is intricate and complex. For example, an architect must understand (or even take on) the roles of the designer, engineer, coordinator, manager and negotiator, with the interfaces between each role being complex. Then, every project has different conditions, because each project has a different context, site, regulation and policy. At same time, it needs to be understood that the main function of each architecture type is completely different from others. To address this a generalized understanding of architecture design and associated processes is required, which may be applicable to other types of products and services.

Broadly the building design process can be divided into nine process steps:

1. Undertake interviews with clients and other initial stakeholder discussions
2. Defined the main function/s and other major conditions and constraints
3. Gather required information and documentation
4. Develop schematic designs and undertake feasibility studies
5. Develop design and permit documents
6. Develop construction documents and acquire permits
7. Develop detail designs and specifications
8. Develop shop drawings for construction
9. Detail finishes and select parts

There are lots of feedback loops associated with this process, between each step in every project, because it is almost impossible to define all elements in each construction project before starting construction site works. The specific context has a large influence on the process, including the influence of stakeholders' organizations, regional factors such as specific regulations to conform to, and social and cultural dimensions to take account of.

Taking the case of skyscrapers in Japan, there was a turning point during the Kasumigaseki Building Project in Tokyo in 1968 [42]. The maximum height regulation of 31m was abolished in that year. The Kasumigaseki Building was 147m, with many new technical challenges needing to be solved. For example, heating due to solar radiation resulted in deformation of the main steel structure, requiring delicate adjustment of each structural column. Also, the designers needed to understand and address several problems arising from the differences in temperature and pressure between the top and the bottom of the building. In order to solve these and other problems the project team became bigger and bigger, leading to many stakeholder groups that had to be consulted and coordinated, including architects, engineers, clients, tenants and management companies.

More than one hundred large-scale meetings were necessary to understand and solve many kinds of problems as quickly as possible to avoid construction delays. Learning from this project was applied to subsequent construction programs, with 'Design, Bid, Build', 'Design and Build' and 'Construction Management Systems' in place. In every type of project team framework, it is clear what aspects of each project should be solved before starting the project, and who should be responsible for these tasks. This means that the creation process changed from an integral design to a modular approach in Japan, inspired by learning from the Kasumigaseki project.

B. Fundamental architecture logic

Based on experience in how architects consider the design of the built environment, it is possible to establish a fundamental architectural design logic that is applicable to all types of products and services. In this context the term 'architecture' takes on a broader definition to that of the professional architect, as all products and system incorporate architectural principles in their design and organization. In the creation process of products, it is possible to understand that there are two main parts: 1) creating design-information, and 2) producing the physical product.

By adopting a design-information view of industries, it is proposed that product architecture may be a significant factor in determining the industrial sectors in which firms are more likely to exhibit competitive performance. More specifically, Japanese firms tend to be more competitive in the manufacture of products with an integral architecture [14]. On the other hand, a prevailing view in the literature is that over time the product architecture of a firm shifts from being integral to modular [12, 15]. There appears to be an inevitability regarding the evolution towards modular architecture. This raises an interesting question regarding the type of architecture adopted by firms that can succeed in maintaining competitiveness over time.

The design-information view of industries considers a product as being design information that is embodied in a particular medium or material [14]. Products comprise physical components, functional elements and interfaces between interacting physical components [41]. A productive resource is considered to be an information asset and the production process is regarded as a system of productive resources, for example, on the factory floor. Production or commercial manufacture is then considered as the repeated transfer of design information from the production process to a material or medium [14].

Fujimoto also highlights that product architecture can include process architecture [14]. Process architecture concerns the correspondence between the components of a product and their production process. The term 'product-process architecture' encompasses production process influences and is used throughout this paper. Existing literature emphasizes two classification methods for types of architecture; modular versus integral.

Ulrich [41] defines modular architecture as *"a one-to-one mapping from functional elements in the function structure to the physical components of the product, and specifies de-coupled interfaces between components"*. On the other hand, integral architecture is defined as *"a complex (non one-to-one) mapping from functional elements to physical components and/or coupled interfaces between components"* [41]. It is important to note that most products do not fully satisfy the definition of either modular or integral architecture [4]. In reality, a type of architecture exists to a certain degree and Fujimoto refers to architecture as a spectrum [14].

Returning to the reference to firms' competiveness in the manufacture of products with an integral architecture, examples of this type of products includes cars, motorbikes, games software and compact consumer electronics [14]. By competitiveness, Fujimoto is referring to both productive and market performance. Productive and market performance in turn influence profit, and competitiveness results from having leading performance in any of these areas.

Shifting to viewing architecture types from a dynamic perspective, an established view is the tendency of products to ultimately become modular over time. Architecture shifts in a cyclical pattern; newer products with changing design elements tend to be integral products and products with stable design elements tend to be modular products [5]. Time facilitates standardization, a characteristic of modular architecture in which the interfaces between components are standardized.

The generic systematic roadmap form depicted in Fig. 3 & 4 is more readily applicable to modular systems. Typically the hierarchical layered structure is designed in a way that various functional modules of the innovation system can be viewed somewhat independently, with the interactions between layers (and functional) modules of the system being minimized. There is good reason to do so, in terms of managing complexity, and many engineered systems are designed on this basis, including the types of products developed by companies where roadmapping first emerged – e.g. Motorola [43]. However, as discussed above, there is a tradeoff between the management of complexity and optimization of the overall system, which can be better achieved through integral design architectures. For such systems the highly structured multi-layer roadmap structure may not be suitable, and less constrained 'freeform' formats may be more appropriate. Less structure is imposed, with more degrees of freedom to express strategy visually. This is illustrated in Fig. 9 for two product-level innovation roadmaps: a) including sub-structure, suitable for modular architectures, and b) without sub-structure, suitable for integral architectures. The functional logic for structuring the product-service-system (PSS) as proposed by Philips [16] may be applicable to both modular and integral architectures, although the interactions (between functions, and layers of the roadmap) will be more complex for integral system design.

C. Emergent functions, key strategic messages and narratives

The fundamental logic of the roadmap framework, as depicted in Fig. 3-8, is one of architectural evolution, depicting how the function and performance of changes over time, in line with market demand and technological capability. Roadmaps are structured with many elements, such as information, knowledge and a sense of values (of those creating the roadmap, and their perceptions of others' values). The structure of the roadmap (Fig. 3 & 4) is designed with the characteristics of product field (PSS) at the center (middle layer), based on a modular architecture that is based on an hierarchical structure of elements.

(a) (b)

Fig. 9 – Product-level roadmaps illustrating different levels of structure, suitable for a) modular and b) integral architectures

The roadmap framework provides a structured 'canvas' and a common visual language that enables key strategic messages and narratives to be constructed and communicated concisely and clearly. For roadmaps that depict the longer-term evolution of products, such as the digital camera examples shown in Fig. 5 & 7, it is necessary to understand the characteristics of a product and the situation of technology diffusion in society.

In the design process of a product, designers tend to adjust internal elements to existing external environment to achieve the intended purpose of the product. Then as a fundamental process, they need to clarify this purpose by understanding the customer (and other stakeholder) needs of a product, and then to adjust manageable elements and complete its design to adapt the product to the external environment. That is, after grasping users' needs, undertaking concept design based on this understanding, leading on to functional and structural design, which are the two general steps in the design processes. Obtaining feedback on each stage if necessary, the structural design is completed in detail, as defined in design documents and specifications. This process applies to both incremental and radical innovation, although is more critical when a major architectural change occurs such as the transition from film to digital to smartphone cameras, which may be associated with disruptive technological and market forces, leading to new functionality and usage patterns.

From the consumers' perspective, they receive the final product without considering or understanding how it was designed and manufactured. For radical products, such as the first generation of film, digital or smartphone cameras, consumers receive products that are novel and which they have never used before. In this situation, users may be uncertain that the product is worth buying or using [36]. On the other hand, for many consumers studying the detailed product instruction manual can be troublesome, and may not be aware of the full range of functions, or how to most easily access and control these functions in the way that the designers envisaged.

Nevertheless, consumers will continue to use the product if certain needs are met and benefits obtained, but may start to create new functional attributes and combinations not intended or expected by the product designer. This user-led experimentation can be a source of innovation and inspiration to designers [21]. This is influenced strongly by user perceptions and behaviors, which may be different those of the designer. Functions created by users are termed 'emergent functions', and should not be ignored by product manufacturers and designers, as this can have a major impact on the diffusion of a new innovation, and also a source of innovation that companies can exploit. Such understanding may also influence the way in which roadmaps are created and depicted, and the associated strategic messages and narratives highlighted. Fig. 10 illustrates schematically how the perspective of designers and users evolve (and differ) through the design process [40].

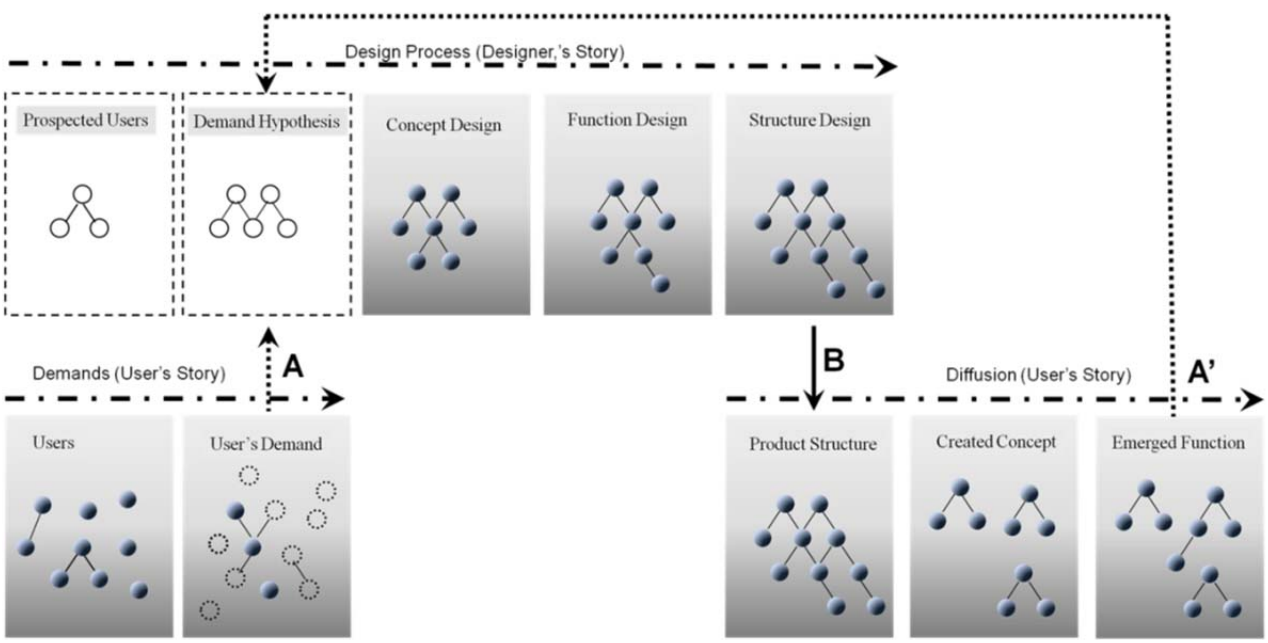

Fig. 10 – Users' story and designers' story in design process

IV. DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

This paper describes initial findings from exploratory research, bringing together two related but different professional perspectives – that of engineering and architecture. The roadmapping technique was developed in technology-intensive industries, such as electronics and aerospace, to support the alignment of technology and commercial perspectives for improved innovation of complex engineered products. The focus, process, structure and expression of roadmapping and roadmaps can be said to have a utilitarian engineering bias, owing to these origins and its continued widespread use within these industries. However, the approach is generic, and has been adopted (and adapted) in other sectors, including construction. Sections I and II of this paper provide a summary of the approach, illustrated with an example of an engineered product (the camera), represent an engineering oriented perspective. The motivation of this exploratory research was to challenge this perspective, through cross-disciplinary discussion, to reflect on how architects think about the design and usage of products in their domain – the built environment.

Several key insights have emerged which, which may have a positive impact on how roadmapping is conceived and deployed:

1. When considering the general nature of technology-intensive product innovation and development, the fundamental roles that architects and engineers play share similarities but also differences. Both professions are concerned with delivering well-designed products, services and systems that meet the needs of their users and other stakeholders. However, as a generalization, engineers place a greater emphasis on the functional utilitarian design of products, while aesthetics and usability are more central to design thinking in architecture as a profession.
   The lack of attention to usability and aesthetic considerations in engineering is evident in the development of roadmapping, where the very practical systematic planning-oriented format depicted in Fig. 3 has become the dominant form, with rather limited attention the graphical design of this and other forms, essential for communication. Roadmapping was originally developed in the late 1970s, is widely used in industry, but these aspects only gained the attention of academics 30 years later [3, 30]. Further attention to this aspect is needed, and would benefit from insights, theories and approaches from the world of architecture.
2. The fundamental design logic that governs the development of products of all types is of course applicable to the disciplines of architecture and engineering. Principles of product and process architecture apply to both complex products such as buildings and also mass-produced products such as cameras. Concepts of integral vs. modular architectural design are also common to both types of products, although many buildings are unique in their design and form, and as large one-off complex products are bespoke in their design, adopting an integral architecture.
   The fundamental structure of the most widely used roadmap form (see Fig. 3 & 4) strongly emphasizes modular architecture, with the roadmap structure based on hierarchical systems principles. The development of roadmaps for products that have an integral architecture is more complex due to the many dependencies that exist between the various elements of the product. Less structured roadmap forms may be more suitable for such systems (see Fig. 9), combined with additional tools such as quality function deployment [27] to map these relationships, to provide a more holistic approach for such systems.
3. The phenomenon of emergent function is apparent in many product types, from buildings to smartphones, where users find new and novel ways of using products that were not anticipated by the original designers. This should be acknowledged by both product designers and roadmap developers, allowing for an iterative approach to better understand user perceptions and behaviors at an earlier stage. Roadmapping has been highlighted as a ‘proactive’ technique [10], with this attribute considered as a benefit as a foresight method, in terms of defining a desired future state, rather than passively responding to external events. However, when considering the nature of emergent function, and the inherent uncertainty associated with predictions about future market and technology conditions, it is worrying that most roadmaps have a strongly convergent form. It would be healthier to acknowledge these uncertainties, and the opportunity to learn from market and user feedback. Roadmaps should depict these aspects, and the roadmapping process should be iterative in order to accommodate this learning.

This research, albeit embryonic and exploratory in nature, highlights the benefits of cross-disciplinary research and engagement. Further discussion and research is planned to explore how roadmapping theory and practice could be improved through application of existing theory and practice from the profession of architecture. Conversely, it is also hoped that that principles and methods from roadmapping and related methods developed in the manufacturing industry can be applied to benefit the activities of architects.

Two related areas in particular would benefit from further cross-disciplinary exploration:

1. Visual form and function of roadmaps, particularly in terms of selecting and designing the most appropriate format for communication of strategy, depending on context. Many visual forms exist (see Fig. 2 for a small sample), but little theory or design practice available. Roadmapping can learn from the profession of architecture, where there is considerable theory and

practical experience of how to convey complex subjects through the use of visual and physical artifacts.

2. It is often said that the process of roadmapping is more important than the roadmap itself, as the structured visual language provided by roadmaps (Fig. 2) enables multiple diverse perspectives to be brought together and aligned. Workshops are often used in roadmapping processes to facilitate this dialogue (see Fig. 9 for outputs of such workshops), and it is possible that the profession of architecture could benefit from such processes, given the many and diverse stakeholders involved.

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