# Sustainable Approaches to the Management of Innovation and Technology in Engineering (SAMITE II)

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## Abstract

Engineering gives rise to some of the most vibrant and fast-paced industries in the world; yet, these industries and innovations can exact a heavy price, impacting people and the planet in the procurement of profits. Growing awareness of environmental issues and concerns over the cumulative environmental impact of extraction, manufacturing and transport have provoked increasing demands for accountability and responsibility; there is a groundswell of opinion that industries must be more transparent. The innovation of new, more sustainable practices cannot be done in isolation: practitioners must work with other professionals, if the needs of all stakeholders are to be respected and embraced.

To address contemporary challenges and create a more sustainable world, graduates must know whom to speak with, why and about what. As a key step towards this, we present a framework to provide a holistic perspective on the intersections of the various value chains that obtain in engineering, manufacturing and product development; this framework makes explicit the many paths through which products and services are created and developed, through what we term 'innovation trajectories'; and the (artificial and natural) contexts from which these draw; this in turn helps to identify key partners from professions and stakeholder groups. Knowing whom one needs to engage with and why directly supports softer skills that are an essential foundation of an effective professional engineering practice. Thus, we also consider this framework a useful mechanism to inform the discussion around employability and professional competence.

## 1 Introduction

Engineering gives rise to some of the most vibrant and fast-paced industries in the world; innovations arise at all stages, from ground-breaking industrial processes and novel materials promising new commercial opportunities, to disruptive business models affording new ways of realising these. But these industries and innovations can often exact a heavy price, impacting people and the planet in the procurement of profits; cf. Elkington (1997) and Savitz and Weber (2006). Growing awareness of environmental issues and concerns over the cumulative environmental impact of extraction, manufacturing and transport have provoked increasing demands for accountability and corporate responsibility (Horrigan 2010). Indeed, there is a groundswell of opinion that industries must be more transparent in their practices and proactively seek to replace the traditional "take-make-waste" model with a 'Circular Economy' (MacArthur 2019).

Responsibility in manufacturing, distribution and use is not a novel idea in Engineering, cf. Life-Cycle Analysis (e.g., Ashby 2005); and engineers themselves are precisely the professionals to rectify such imbalances: reconciling and resolving contradictions is fundamental to an engineer's mindset; recall, for example, TRIZ (Altshuller 2006). Such redress requires the "creative destruction" of established processes (Schumpeter 1934) and the innovation of new, more sustainable practices. And this cannot be done in isolation: engineering systems, and *a fortiori* engineering itself, are systems within larger system; thus, practitioners must work in teams with other professionals to accommodate the needs of all stakeholders, i.e., those affected by the outputs—concepts, systems, products—of their industries. Quite simply, to create a more sustainable world, engineering graduates must know whom to speak with, why and about what.

As a key step towards this, we present a framework that extends the SAMITE workspace of Stalker, Desai and Studd (2011) to provide a holistic perspective on the intersections of the various value chains that obtain in engineering, manufacturing and product development; this framework makes explicit the many paths through which products and services are created and developed (what we call "innovation trajectories") and the (artificial and natural) contexts from which these draw; this in turn helps to identify key partners from professions and stakeholder groups. Knowing whom one needs to engage with and why directly supports softer skills that are an essential foundation of an effective professional engineering practice. Thus, we also consider this framework a useful mechanism to inform the discussion around employability and professional competence; cf. Knight and Yorke (2004) and Dacre Pool and Sewell (2007).

In Stalker *et al* (2011) we presented SAMITE, a framework for systematically managing innovation and technology in textiles. We have since enriched the underlying thinking with explicit recognition of sustainability that obtain within this framework and have extended our application to the support of courses, projects and education in other areas, including engineering. Here, we seek to present the fundamentals of the framework as it currently stands and outline its application. The structure of the paper is as follows: in Section 2, we clarify "management of innovation" and elaborate "sustainable approach"; in Section 3, we present our workspace, identifying the ingredients that combine in its construction

## 2 Background

### *2.1 Innovation and Management*

Our starting point is the definition of the *management of innovation* offered by Bruton and White (2011, p.379): a "comprehensive approach to managerial problem solving and action based on an integrative problem-solving framework, and an understanding of the linkages between innovation streams, organizational teams, and organization evolution". We underline the need for an 'integrative problem-solving framework' with explicit 'linkages': our attention framework embraces these aspects. Innovation is the synthesis of technology and business: both are fundamental to innovation; cf. Schumpeter (1934). The 'innovation arena' of Janzsen (2000) comprises four key aspects—technology, application, markets (or user groups) and organisation (the TAMO combination)—to make explicit this synthesis; see Figure 2. He uses this to both frame the context that must be considered when studying innovation and to delineate the scope of the innovation activities. Thus, to truly understand innovation requires a holistic view of the TAMO combination; moreover, the interactions of the TAMO combination evolve over time tracing out 'innovation trajectories'[1]: for example, new technology is used to create a new application, which in turn

[1] Traditionally, the innovation trajectory is drawn beginning at the market axis: this is not to suggest that all innovations begin there.

creates a new market; this in turn may stimulate new organisational forms to better exploit the potential of this.

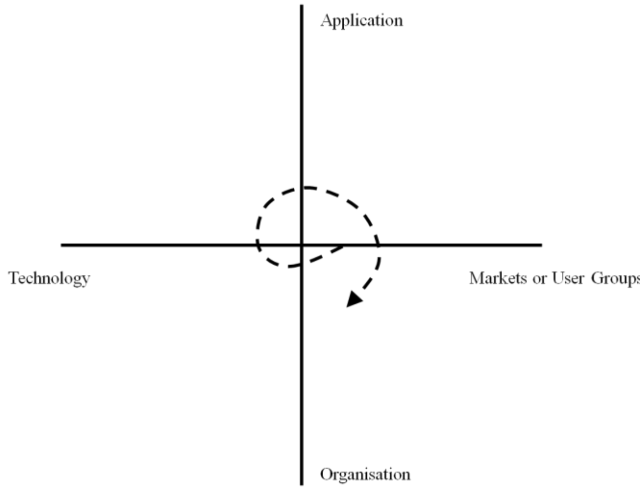


Figure 1: The Innovation Arena (TAMO**)** [*after* Janzsen (2000)]

Recognising the need to continually assess the impact and influence of drivers from each aspect of the TAMO combination motivates a framework that explicitly identifies the components of each aspect in sufficient detail to allow these influences to be traced.

### *2.2 Sustainable Development and the Circular Economy*

There are many uses of the terms ‘sustainability’ and ‘sustainable development’; perhaps the most oft-cited definition of sustainable development is that of the Brundtland report (WCED 1987): “development which meets today’s needs without compromising the ability of future generations to meet theirs” (p. 41).

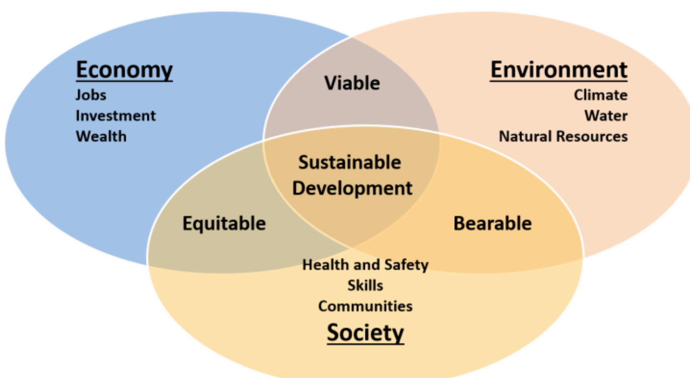


Figure 2: Sustainable Development

While this presents a useful starting point, we prefer a more wholistic conceptualisation that recognises the three pillars of Elkington (1997), see Figure 2: unless there is explicit consideration of the needs of people (society) and economic viability in conjunction with responsible curation of the environment, we will not have a truly sustainable approach; cf. the observation of *inter alia* Savitz and Weber (2006) that sustainable development arises where “business interests and the interests of the environment and society intersect”.

## 3 The SAMITE Workspace

Our workspace draws on a number of primary sources which reflect our backgrounds of interaction and expertise; but it is built by elaborating upon and refining an 'information structure for product design' developed by Ashby and Johnson (2010, p.126), see Figure 3; this clarifies the interactions of various categories of information. While technical design, e.g. Ashby (2005), is motivated chiefly by the attainment of function, subject to minimum cost and required quality, safety, etc., excellent product design considers aspects such as appeal, ergonomics, usability, perceptions, etc.; broadly, *personality* and *usability*. These are essential to the development of successful products: great products function, satisfy and even delight.

A particularly appealing aspect of this structure is the clear separation of elements which procure the physical structure of the product—thus, the technical aspects—from those that combine to create an effect that stimulates, satisfies and pleases the target user; these are referred to as *physiology* and *psychology*, respectively. Naturally, these two areas interact: for example, the use of certain materials will serve to support aesthetic characteristics or perceptions, e.g. the use of polished metal to suggest high technology or woods to connote craftsmanship. Further, Ashby and Johnson (2010) make explicit the target market (*intention*) for the product: this will influence both the physiology and the psychology of the final product.

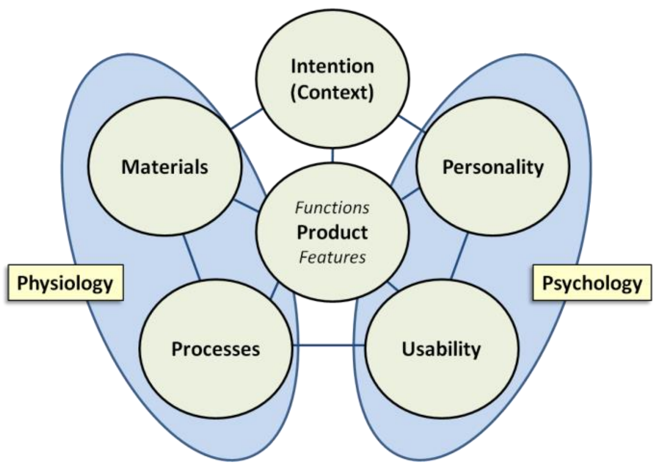


Figure 3: Product Design Information [*after* Ashby and Johnson (2010); cf. Ashby (2005)]

This structure provides the means to begin exploring the technology and markets aspect of the TAMO combination; the product itself can be used to understand the application areas. Yet, this represents only a starting point: notions of *personality* and *usability* do not always capture the engagement of an end consumer with the artefacts produced; moreover, very few products are sold as standalone items: there is typically a 'wrapper' of services and experiences. Thus, we extend the notion of a 'product' to include services and we distinguish business processes from manufacturing processes. We adopt the term 'value proposition' to denote products, services and combinations of these (so-called 'product-service bundles').

### *3.1 Elaboration of the Basis*

Elaboration of the basis consists in the development of the structure of Ashby and Johnson (2010) using additional elements that complement and refine. These 'extensions' provide the means to characterise the psychology of goods, services and experiences; to provide elements that describe a physiology of product-service bundles; and the direct inclusion of financial aspects such as revenue streams and cost structures. We developed these in Stalker *et al* (2011); thus, we move directly to an overview of the 'workspace'.

### *3.2 Workspace: Framework, Innovation Trajectories and Spiralling*

Our workspace comprises: a framework (see Figure 7) that coordinates elements essential to a full characterisation and understanding of a product-service bundle, its composition and interaction with users and markets; and 'innovation trajectories' that describe routes through the framework.

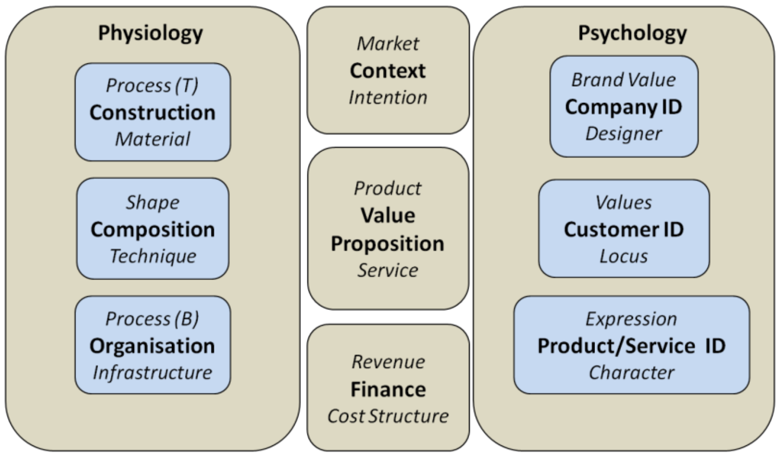


Figure 4: The SAMITE Workspace (Stalker *et al* 2011)

**Value proposition** denotes the bundle of products and services offered. It acts as a focal point of the framework, since it is the ultimate offering.

**Physiology** denotes the structural aspects of the value proposition; it comprises

- **Construction** which treats the physical form, material(s) and the technical process(es) employed.
- **Composition** which addresses design approach(es), specific shape(s) and technique(s) applied.
- **Organisation** which addresses the means through which the value proposition is brought to market; it also addresses the intangible analogue(s) of physical form for services; it consists in business processes and the organisational infrastructure or ecosystem.

**Market** captures the commercial context, identifying target customer(s), i.e. market(s), and design intention.

**Finance** captures the revenue stream(s) through which the value created will be appropriated and makes explicit the cost structure(s) involved in creating and delivering the value proposition.

**Psychology** denotes the intangible aspects of the value proposition; it follows the product expression model of Gotzsch (2006) and comprises Company ID, User ID[2] and Product/Service ID.

Fundamentally, the framework is a clarifying structure: it elucidates aspects to be evaluated and considered; it identifies potential roles where teams coordinate their efforts; and it gives suggestions of whom, i.e. what categories of experts, to approach to realise an innovation.

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[2] Here, we use 'locus' to signify expressions of time, place, status and culture.

### *3.3 Innovation Trajectories*

Innovation can arise in any area of the framework; we refer to the driver or motivator of an innovation as an '(innovation) epicentre'; cf. Osterwalder and Pigneur (2010). An '(innovation) trajectory' is a path through the framework; it begins at an epicentre and visits each main area; it is descriptive rather than prescriptive or normative. Tracing possible trajectories clarifies how to bring an innovation to market, e.g. what to consider and whom to consult. Figure 5 illustrates two generic trajectories.

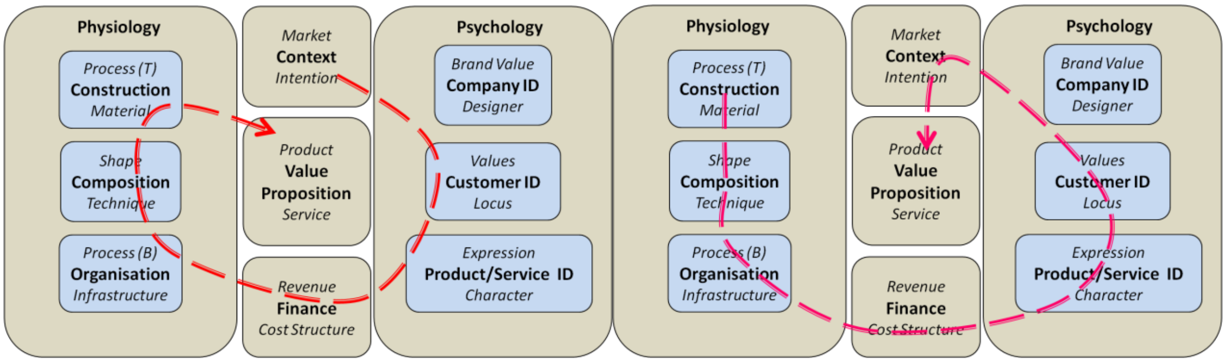


Figure 5: Market-Driven and Process-Driven Innovation Trajectories (Stalker *et al* 2011)

The left-hand side of Figure 5 illustrates a trajectory with an epicentre in 'context'; specifically, from market intelligence and we refer to this as a 'market-driven innovation trajectory'. The driver for the innovation is a new market opportunity. Here, a profile of the target customer is developed and used to define a product-service bundle to meet a potential demand. If the market opportunity can be clarified in terms of price, then the product-service bundle definition can be augmented with strategic pricing and an appropriate (target) cost structure. This cost structure is likely to influence the choice of business processes, composition techniques and the physical construction of the final offering. To refine the choices and decisions that will ultimately lead to the value proposition, the trajectory will be traced a number of times; each tracing provides opportunities to explore the economic viability of the value proposition, the social contribution and costs of the activities developing the value proposition and the environmental/ecological impact of delivering the value proposition. The right-hand side of Figure 8 illustrates a trajectory with an epicentre in 'physiology'; specifically, from the development of a new (technical) process and we refer to this as a 'process driven innovation trajectory'. Perhaps, this new process is more environmentally friendly, with lower carbon footprint or the reduced need for irrigation; it may require new composition techniques or provide the possibility of new shapes; these in turn may require a reorganisation of existing (business) processes or suggest the opportunity of new partnerships, leading to a revised infrastructure. Attendant cost structures need to be investigated to determine the most appropriate route to the development of new product-service bundle definitions and identification of profiles of customers most likely appreciate the potential offerings; this will be informed by intelligence regarding market opportunities. Again, to refine the choices and decisions that will ultimately lead to the final value proposition, the trajectory will be traced several times. Often, an innovation will unite and unify a number of developments; for example, a new market opportunity may coincide with the development of a new process, e.g., the more ethically minded consumer demands more sustainable fabrics that can be realised through the use of 'newer' fibres such as bamboo. In this case, we consider multiple trajectories from multiple epicentres and refer to the coordination of the individual trajectories into a single trajectory as '(innovation) trajectory alignment'.

These invite the coordination of efforts from different disciplines and gives a clear motivation for the need to educate the engineers and other graduates of the future in the context of product-service developments.

### *3.4 Summary Case Study: Electric and Hybrid Electric Vehicles*

Innovation and sustainability unify in the development of electric and hybrid electric vehicles (EV/HEVs). The desire to reduce (urban) emissions has motivated significant investment in research into replacing internal combustion engines (ICEs) (DoT, 2020): EV/HEVs promise the means (Kumar and Alok, 2019).

Increasing adoption of EV/HEVs, suggests exploring this as a market-driven trajectory through the SAMITE workspace. With the market as the driver, and the strength of the brand and reputation for innovation (Company ID) will strongly influence offerings. A premium brand may introduce a new HEV alongside its existing range or perhaps deploy key technologies across multiple platforms to preserve the key characteristics of the products (Product/Service ID) in the perceptions of its key customer base (Customer ID). If the customer base is to be enlarged, then when retracing the trajectory, it would need to explore this part of the trajectory from Market to Psychology to Finance in depth. This provides a perfect opportunity to explore the three pillars of sustainability within an innovation trajectory: in particular, environment as a key driver with the constraint of retaining prestige in eyes of key customers to preserve economic viability. The brand would need to examine whether it could offer a suitably differentiated product (automobile) to justify the price point: would the EV/HEV 'speak' to the customer in the 'same' way? Does a branded EV/HEV convey the status (Product ID)? Jaguar Land Rover (JLR) has HEVs targeting the 'premium' customer (Product ID), which seem preserve the brand meaning (Company ID). The exploration of economic viability would also be informed by potential future revenue streams (Finance). For example, JLR is investing in its own battery power R&D initiatives and development, utilising the resources from its parent group, Tata Motors (Organisation); licensing offers a possible future revenue stream. Of course, the structure and production of cars with ICEs is different: there are significant changes in the elements of 'physiology' (Composition and Construction). Owing to space, we defer discussion.

## 4 Discussion: Communication and Employability

SAMITE provides a workspace to explore and clarify sustainable paths to the management of innovation. In a forthcoming work we present its application to further case studies across disciplines, including product development in aerospace and recyclable textiles. The notions of epicentre and trajectory afford the means to pursue the management of innovation in a systematic manner. These structures to foster communication; this is achieved in two stages: an explicit statement of the vocabulary of each area; and an alignment of these at interfaces. Making explicit the many paths through which products and services are created and developed and the (artificial and natural) contexts from which these draw helps to identify key partners from professions and stakeholder groups. Knowing whom one needs to engage with and why directly supports softer skills that are an essential foundation of an effective professional engineering practice; for example, it explicitly supports the 'personal and professional skills' components of the CDIO framework (www.cdio.org); the structures can be used to structure interdisciplinary project teams, which supports the 'interpersonal skills' component of the CDIO Framework (and of course other professional frameworks, such as UKSPEC). Thus, the SAMITE framework is a useful mechanism to inform the broader discussions around employability, contributing directly to development of a fuller understanding of the context of ones subject, confidence in knowing how to assemble an appropriate team to address challenges, and reflection on the need to engage with stakeholders; cf. Understanding, Efficacy and Metacognition in the USEM model of Knight and Yorke (2004).

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