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A shift in communications infrastructure is an important factor in how open design has taken shape and the possibilities it offers. It is a transition from the 'internet of things' to the things of the internet. Michel Avital analyses the main drivers behind open design, open innovation and open source. He describes the major features of open design and explores the preconditions for open design in relation to four aspects: object, process, practice and infrastructure, with a specific focus on infrastructure.

Michel Avital

'Openness' is a recurring and increasingly frequent theme in recent buzzwords that populate the discourse on the forefront of technology, from *open source* via *open innovation* to *open design*. A review of related articles in the popular press and trade magazines indicates that the modifier *open* often denotes better, cheaper and faster. Apparently, the qualities inherent in openness or being open have materialized as the underlying enablers that pave the way for creativity, innovation and prosperity. In keeping with the thrust of this volume, this article contextualizes open design, focusing in particular on the characteristics of the infrastructure that are most conducive to its generative capability in relationship to innovation.

The Context of Open Design

Openness pertains to accessibility. Openness is a relative characteristic that refers to the degree to which something is accessible to view, modify and use. The ability to *view* refers to sharing **SHARING** content and the availability of detailed information about the subject matter. The ability to *modify* refers to sharing labour and empowering changes, improvements and extensions of subject matter. The ability to *use* refers to sharing ownership and enabling semi or unrestricted reuse of the subject matter or parts thereof. These are the three fundamental operations that are implied by accessibility. Subsequently, from a systems theory perspective, openness relates to the transparency and permeability of any natural or constructed boundaries. Yet openness is not merely a technical attribute that conveys flow or lack thereof; it is an embedded trait that pervades the structure of a thriving civil society. From a social perspective, openness is a core characteristic of an infrastructure that conveys and reinforces sharing, reciprocity, collaboration, tolerance, equity, justice and freedom. The application of openness, **OPEN EVERYTHING** as implied by various accessibility features, to a growing number of central ubiquitous practices that drive the human enterprise, has turned into a megatrend that can be labelled the *Rise of Open-X*. Megatrends are widespread trends which have a major impact and are likely to affect all levels – individuals, organizations, markets, countries and civil society – for a long duration. Understanding megatrends **TRENDS** and their rolling effects can provide valuable

information for developing futuristic scenarios and can subsequently help to shape current actions in anticipation of that future. So far, as described below, Open-X has materialized in various configurations that can be classified according to three archetypes: open innovation, open source and open design. The three archetypes are juxtaposed in the table on the previous page as a preliminary overview to point out their different respective value propositions and thrust (as a distributed collective action), core openness orientation, and prime actors involved.

JUXTAPOSING ARCHETYPES OF OPEN-X

OPEN INNOVATION

OPEN SOURCE

OPEN DESIGN

	OPEN INNOVATION	OPEN SOURCE	OPEN DESIGN
VALUE PROPOSITION AND THRUST	DISTRIBUTED KNOWLEDGE	DISTRIBUTED DEVELOPMENT	DISTRIBUTED MANUFACTURING
CORE OPENNESS FACET	VIEW	MODIFY	USE
PRIME ACTORS	ORGANIZATIONS	DEVELOPER COMMUNITIES	CONSUMERS

Open Innovation

The value proposition and thrust of *open innovation* is 'distributed knowledge' processes that emphasize the *view-related* capabilities of openness. The prime actors of open innovation are organizations. According to the traditional doctrine, industry leaders self-create the most and the best ideas; innovation should therefore be fostered by internal development teams behind high organizational walls and protected as a trade secret. In contrast, according to open innovation, industry leaders make the best use of internal and external ideas to develop better business models. In other words, superior outcome should be expected with permeable boundaries between a firm and its environment, which allow idea flow, knowledge

KNOWLEDGE exchange, and intellectual property trade. Reaching out and tapping into external knowledge resources extends the generative and innovative capabilities of a firm, as demonstrated by industry leaders like Procter & Gamble, Boeing, Philips and many others. The tenets of open innovation have promoted the proliferation of communities of practice and laid the foundations of crowdsourcing. **CROWDSOURCING**

Open Source

The value proposition and thrust of *open source* is 'distributed development' processes that emphasize the *modification-related* capabilities of openness. The prime actors of open source are developers. The open source concept originated in the software industry; according to the traditional doctrine, software is developed in commercial software firms by professional personnel, guarded through legal and technical measures, and then licensed for a fee. In contrast, according to the open source business model, software is developed through coordinated peer production by independent volunteers.

THE APPLICATION OF OPENNESS TO A GROWING NUMBER OF PRACTICES THAT DRIVE THE HUMAN ENTERPRISE,

HAS TURNED INTO A MEGATREND THAT CAN BE LABELED THE RISE OF OPEN-X.

Subsequently, everyone can freely access the source code, and can modify and redistribute it under the same terms, thus nourishing continuous cycles of improvement, adaptation, and extension in a distributed fashion. Reaching out and tapping into external development resources extends the generative and innovative capabilities of a core project. Inspired by the impact of high-profile projects like Linux and Mozilla Firefox, the tenets of the open source development, licensing and distribution model have promoted the proliferation of open source projects of all sorts – from digital content development (e.g. Wikipedia), via vehicles (e.g. c,mm,n) and beverages (e.g. Free Beer – Vores øl), to 3D printers (e.g. RepRap), just to name a few. **OPEN EVERYTHING**

Open Design

The value proposition and thrust of *open design* is ‘distributed manufacturing’ processes that emphasize the *use-related* capabilities of openness. The prime actors of open design are consumers. Although designers undoubtedly play a pivotal role in fostering open design by producing and sharing suitable design blueprints, **BLUEPRINTS** ultimately the consumers who engage in distributed manufacturing are the core players and *raison d’être* of open design. According to the traditional doctrine, design is mostly a preliminary stage prior to commercial manufacturing and distribution. In contrast, open design is directed toward consumers who engage in fabrication, passing over the conventional manufacturing and distribution channels. Open design implies that the design blueprints are publicly available, sharable, licensed under open-access terms, and distributed digitally in a general design specification file format (e.g. dxf, dwg). Moreover, open design is not black-boxed or exclusive; it implies reconfigurable and extensible design that can be fabricated in distributed and scalable fashions through commercially available, off-the-shelf, multi-purpose means of production.

A structured description of the unique features and boundaries of open design is provided in the table on the next page. The inherent reconfiguration and extension potential of a user-driven open design reinforces the generative and innovative capabilities of consumers. The tenets of open design have inspired the development of public manufacturing facilities networks like Fab Lab, and laid the foundations of open design clearinghouses like Ponoko, Shareable and Instructables. In summary, the distinctions between the three archetypes of Open-X are more a matter of thrust and areas of application. They are not mutually exclusive. All three inherit the core features of openness and naturally overlap to some degree. Open design, for example, is not merely a matter of re-use and distributed manufacturing – it also entails sharing design blueprints and sharing extensions thereof, thus distributing knowledge and development. Building on the working definition of open design and an understanding of its unique features, the remainder of this article will discuss its potential, in particular addressing the infrastructure characteristics that are most conducive to its generative capability in the context of innovation.

Unpacking Open Design

Open design signifies open-access digital blueprints that can be adapted at will to meet situated requirements, and can subsequently be used by consumers to fabricate products on demand by commercial, off-the-shelf production methods. The open design model diminishes the traditional vertical value chain that is formed by designer-manufacturer-distributor-consumer relationships and offers an alternative, open web of direct links between designers and consumers. The resulting short-spanned, transient and non-hierarchical relationships forge dynamic and flexible arrays of blueprints that are not only user-centred but also user-

driven.

The discourse on open design encompasses a multitude of considerations: for example, design specification, fabrication, collaborative action, supply and value chain management, business models, legal aspects, technological infrastructure and normative values. The complexity of this ecology can be untangled to some extent by classifying the underlying issues of open design into four interdependent conceptual layers, as follows:

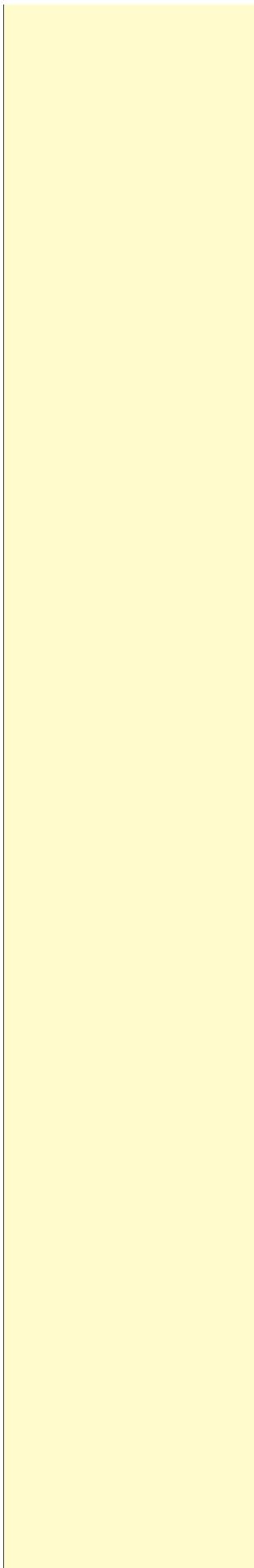
Object layer refers to the *design blueprints* that enable and constrain the specification of the design artefacts. This layer encompasses the design and distribution of open design objects, that is, configurable and extensible blueprints that are available under open access license in online public repositories.

Process layer refers to the *means of production* that enables and constrains the fabrication of the design objects. This layer encompasses open design fabrication, that is, the application and operation of commercial, off-the-shelf machinery like printers, PRINTING laser cutters or CNC machine tools to produce customized products with no custom-built moulds or machines.

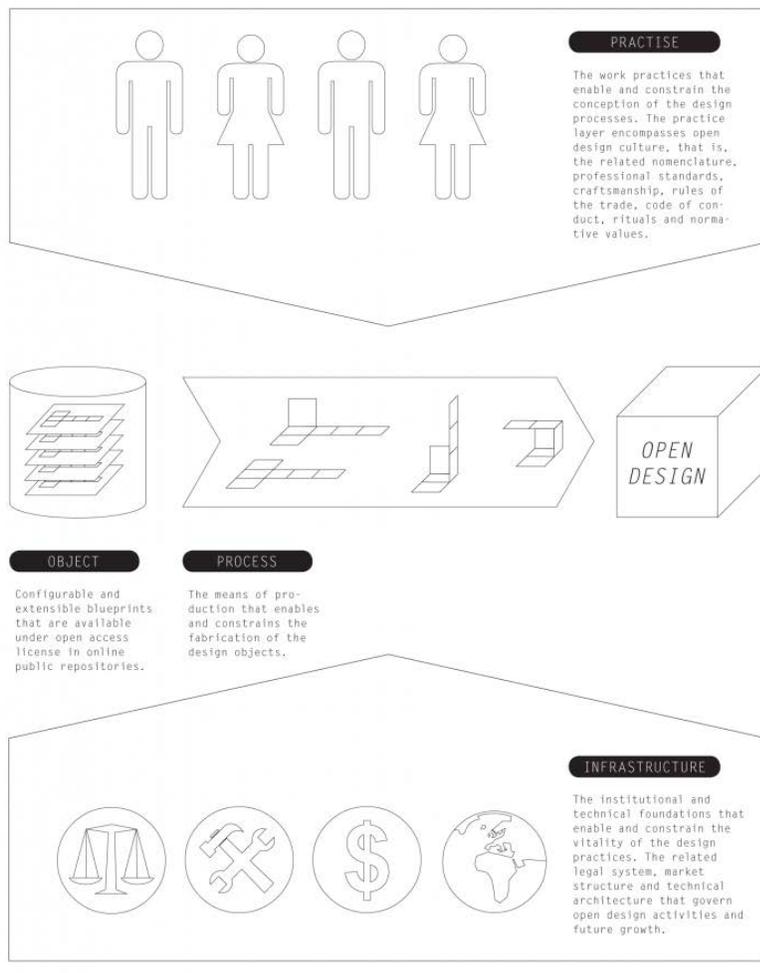
Practice layer refers to the *work practices* that enable and constrain the conception of the design processes. This layer encompasses open design culture, that is, the related nomenclature, professional standards, craftsmanship, rules of the trade, code of conduct, rituals and normative values.

Infrastructure layer refers to the underlying *institutional and technical foundations* that enable and constrain the vitality of the design practices. This layer encompasses open design substructure, that is, the related legal system, market structure and technical architecture that govern open design activities and future growth.

The discourse so far is focused on the object and process layers, with some touches upon the practice layer. However, quite surprisingly, despite its fundamental role, the infrastructure layer is virtually ignored.



LAYERS OF OPEN DESIGN



Designing Generative Infrastructure

The infrastructure that governs open design activities, business models and development is based on the related code of law, market structure and technical architecture, which together enable and constrain most human activity systems in an attempt to balance inherent conflicts and pursue the common good. In a general sense, infrastructures are designed to promote fairness, wealth and operational efficiency. **TEMPLATE CULTURE** Much has been written about the general nature of infrastructures elsewhere, leaving no need to reiterate it here. Instead, let us elaborate on the generative capability of infrastructure as an additional area of concern that should be considered particularly in the context of developing infrastructure requirements for open design. In view of the generative character of design in general, and open design in particular, developing an appropriate infrastructure should aim to incorporate the structural features that are most conducive to creative processes and products. Building on the concept of *generative design*, I suggest a set of generalizable considerations for designing such infrastructures. More specifically, I propose that the infrastructure of open design should be evocative, engaging, adaptive, and open.

Generative design refers to the design considerations in developing an array of artefacts and interactions that support and enhance *generative capacity* – that is, the considerations in designing systems that are conducive to the ability of a person or group to produce new configurations and possibilities, to reframe the way we see and understand the world, and to challenge the normative status quo.

¹ People's generative capacity is a key source of innovation; by definition,

generative design aims to encapsulate the design directives that enhance and complement that human capability.

In general, generative capacity refers to having an evocative power or aptitude that can result in producing or creating something, or tapping into a source of innovation. In the context of open design infrastructure, the modifier 'generative' denotes that the noun it modifies is conducive to the production of something innovative or the discovery of new and hitherto unknown design alternatives. In other words, generative design refers here to the design requirements and considerations in developing open design infrastructures – that is, the related code of law, market structure and technical architecture – that augment people's natural ability to innovate. Subsequently, four top-level design directives are suggested for infrastructures, as follows:

Generative infrastructure is evocative

Generative infrastructure inspires people to create something unique. It evokes new thinking and enables them to translate their ideas into a new context. The infrastructure can help to create the environment or conditions that are prone to those insights by generating and juxtaposing diverse frames that are not commonly associated with one another within an underlying context. Systemic features that drive evocative design enable, for example, seeing an object or situation from multiple perspectives, testing it in multiple situations, examining it at multiple degrees of granularity, and exploring multiple overlay configurations.

Generative infrastructure is engaging

Generative infrastructure is enchanting and holds the attention of people by inducing their natural playfulness and 'flow experience'. The infrastructure **TEMPLATE CULTURE** can help in the creation of engaging environments or platforms that stimulate the users' cognitive spontaneity and playfulness as well as overall positive affect state, thus encouraging further exploration, tinkering and experimentation. Systemic features that drive engaging design enable, for example, fostering positive affect and high spirit that stimulate a state of 'joie de vivre', activating cognitive spontaneity induced by playfulness, and stirring up curiosity through intriguing challenges.

Generative infrastructure is adaptive

Generative infrastructure is flexible and conducive to effective use by a heterogeneous set of people in their own respective environments and for various tasks within an intended scope. It can be adapted with respect to the type of users or groups that it serves in diverse problem spaces. It is also simple to understand and easy for anyone to master. The infrastructure can help in the creation of adaptive systems or platforms that are flexible yet powerful enough to enable the generation of a continuous stream of new ideas and configurations. Systemic features that drive adaptive design enable, for example, user-induced tailoring and customization to meet situated needs, self-production of complementary extensions and features that meet new or initially unforeseen needs, automatic system-induced adaptation, and overall scalable functionality with no regard to size-related attributes.

Generative infrastructure is open

Generative infrastructure accentuates permeable boundaries and transparency that promote co-production, cross-fertilization and exchange of any kind. The infrastructure **ARCHITECTURE** can help in the creation of open systems or platforms that provide connectivity, enable transparency, allow information sharing, and encourage dialogue with no regard to institutionally or culturally imposed boundaries. Systemic features that drive open design enable, for example, free and unrestricted access to information, communication among all stakeholders, and the easy integration of third-party extensions by independent boundary-spanners. In summary, from the generative requirement perspective, infrastructures of open design should be evocative, engaging, adaptive and open.

However, while the last two directives are clearly implied in the discourse of open design, the first two have not yet been addressed. Subsequently, the inclusion of evocative and engaging features in the infrastructure of open design, let alone in the discourse concerning its requirements, is strongly recommended. Although this conclusion might not be obvious for legislators, policymakers, managers, and engineers, it should be quite intuitive for designers. The expected proliferation of open design has far-reaching implications that are likely to extend well beyond design practices as such and have significant socio-economic effects on a global scale.

THE DISTINCT FEATURES OF OPEN DESIGN

	OPEN DESIGN IS...	OPEN DESIGN IS NOT...
ACCESS	AVAILABLE, SHARABLE, LICENSED UNDER OPEN-ACCESS TERMS	CONCEALED, PROTECTED, LICENSED FOR A FEE
BLUEPRINTS	SPECIFIED BY COMMON DIGITAL NOTATION LANGUAGE	SPECIFIED BY PROPRIETARY NOTATION LANGUAGE
DERIVATIVES	RECONFIGURABLE AND EXTENSIBLE	BLACK-BOXED AND FIXED
EXCLUSIVITY	REPRODUCIBLE	LIMITED TO A FINITE SERIES OR ONE-OFF
MEANS OF PRODUCTION	FABRICATED BY COMMERCIAL, OFF-THE-SHELF, MULTI-PURPOSE MACHINES	FABRICATED BY ARTISAN HANDWORK, CUSTOM-BUILT MACHINES OR MOULDS
MANUFACTURING PROCESS	SUBJECT TO DISTRIBUTED AND SCALABLE PRODUCTION	SUBJECT TO CENTRALLY CONTROLLED AND PRESET BATCH PRODUCTION
POTENTIAL	GENERATIVE	CLOSED-ENDED

Another Brave New World

Open design presents entrepreneurs and agile companies with a grand opportunity to expand existing markets, to develop new ones, and to capture large shares from current market leaders. Mobilizing open design to generate organizational value and to boost its market position requires radical strategic and operational changes. However, the tight coupling between design and production, which has so far been instrumental in fostering economies of scope and competitive advantages for the current industry leaders, is now likely to hinder their agile capability and their ability to take advantage of the new vistas that are beginning to be afforded by open design.

PEOPLE'S GENERATIVE CAPACITY IS A

KEY SOURCE OF INNOVATION; BY DEFINITION, GENERATIVE DESIGN AIMS TO ENCAPSULATE THE DESIGN DIRECTIVES THAT ENHANCE AND COMPLEMENT THAT HUMAN CAPABILITY.

The adoption of open design practices by established industry leaders, let alone run-of-the-mill manufacturers, where the dominant culture and mode of product design has been shaped and reshaped over long periods, is likely to pose multiple challenges to these organizations at all levels, from the boardroom to the production floor. Subsequently, the resistance to change in these organizations is expected to reinforce the current tight coupling between product design and industrial manufacturing. Just as Amazon could conquer the market share of established retailers that were unable to adapt quickly enough to the new marketplace of e-commerce, emerging market players based on open design business models are likely to cannibalize the turf of established manufacturers that are entrenched in the old model of industrial production.

From Push to Pull

Open design paves the way to the next iteration in the massive shift from push to pull business models. In general, push business models are based on top-down value chains where a line of a few mass-produced products is distributed broadly through value-driven downstream marketing techniques. In contrast, pull business models are based on bottom-up value chains where a line of customer-configured products are distributed individually through features-driven upstream marketing techniques. Whereas push models are based on economies of scale and emphasize cost efficiency, pull models are based on flexible manufacturing and emphasize mass customization. In previous centuries, most artefacts – from shoes to carriages – were custom-designed and built on demand by a craftsman. Building on push business models, the industrial revolution almost wiped out cottage manufacturing and shifted its lion's share to production lines and mass-scale manufacturing in factories that offer economies of scope and scale. Consequently, the resulting abundant supply of affordable products was instrumental to massive market expansion, higher living standards, and growing wealth across the board. This prosperity has come at the expense of product variety and personalization, as most notoriously conveyed by Ford's remark "any color as long as it's black". **MASS CUSTOMIZATION**

OPEN DESIGN INFUSES 'DO IT YOURSELF' WITH A WHOLE NEW MEANING THAT GOES FAR BEYOND COST SAVINGS OR THE JOY OF CRAFTING.

The advent of the internet has bestowed a new communication infrastructure that made it possible not only to exceed the economic accomplishments of industrialization, but also to offer an unprecedented variety of products and personalization thereof. The latter has been accomplished through pull business models and upstream marketing that take advantage of automated fulfilment and logistics centres supported by fast, wideband, many-to-many communication networks. The extent of product variety and personalization has been attained and fortified in three main phases enabled by the accessibility (i.e. ability to view,

modify and change) afforded by the internet. In the first phase, *retailers* have introduced consumers to the ability to view up-to-date, rich and targeted information about off-the-shelf products, thus enabling them to make informed decisions. Then, in the second phase, *manufacturers* have introduced consumers to the ability to *modify* base products and specify a customized configuration thereof, thus enabling them to fine-tune a product according to their preferences. Finally, in the still-nascent third phase, *designers* have introduced to consumers the ability to *use* blueprints for self-managed fabrication, thus enabling them to gain full control over the features of the resulted product as well as its production process. In summary, as in a stage model, every phase builds upon the previous one to bring the consumers closer to the designers and to provide them with more control over what they get, how it is produced, and how it is delivered.

The Road Ahead

Open design is still nascent, yet it provides a springboard for radical changes in the way we acquire almost anything that is currently mass-produced. Open design presents a new way of design that complements new methods of fabrication, commonly branded as 3D printers **PRINTING** of all sorts. Open design infuses 'Do It Yourself' with a whole new meaning that goes far beyond cost savings or the joy of crafting. It allows consumers to be in charge and offers them an opportunity for full customization of an artefact, including a choice of features, materials and delivery options. It allows for continuous innovation and localization, which in turn has major implications for consumers in shoestring economies as well as in developed countries. It also provides a fertile ground for the development of new forms of organization, new business models, new supply chain structures, new varieties of products and services, and the like, as demonstrated in the many cases in this volume. Nonetheless, traditional design and mass manufacturing practices have been extremely valuable since the Industrial Revolution **REVOLUTION** and are unlikely to disappear in the future. Although the threat to the dominant technologies and practices may seem implausible, open design presents a clear alternative that may grow strong once it reaches a critical mass in the right socio-economic conditions. Open design is not a threat to designers' livelihood. Quite the contrary; it opens new vistas and new opportunities and is likely to generate increased consumer appreciation of the role of designers. Moreover, it is likely to bring designers closer to the intended and unintended applications of their designs. Grand opportunities also imply undeveloped land. There is much development to do in all four layers of open design – the object, process, practice and infrastructure layers. To a large extent, the discourse mirrors the field; the most immediate attention is required in shaping practices and laying the foundations of the support infrastructures.

Conclusion

It has been suggested that open design stands for accessible design in the form of blueprints that are publicly open to view, modify and use under open-access terms. Moreover, open design often implies that the design blueprints are available via open-access digital repositories, that they can be adapted at will to meet situational requirements, and that they can be used by consumers to fabricate products on demand by commercial, off-the-shelf means of production. **DOWNLOADABLE DESIGN** Open design is generative. It is conducive to continuous re-design, adaption, refinement and extension. Open design is a potent elixir that mitigates stagnation and awakens generative action.

1. See Avital, M. and Te'eni, D, 'From Generative Fit to Generative Capacity: Exploring an Emerging Dimension of Information Systems Design and Task Performance', *Information Systems Journal*, 19(4), 2009, p. 345-367.