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Article

Digital Information and Value

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Abstract: Digital information changes the ways in which people and organisations interact. This paper examines the nature of this change in the context of the author's Model for Information (MfI). It investigates the relationship between outcomes and value, selection processes and some attributes of information and explores how this relationship changes in the move from analogue to digital information. Selection processes shape the evolution of information ecosystems in which conventions are established for the ways in which information is used. The conventions determine norms for information friction and information quality as well as the sources of information and channels used. Digital information reduces information friction, often dramatically, and changes information quality. The increasing use of analytics in business increasingly delivers predictive or prescriptive digital information. These changes are happening faster than information ecosystem conventions can change. The relationships established in the paper enable an analysis of, and guide changes to, these conventions enabling a more effective use of digital information.

Keywords: information; selection; connection; digital; analytics; agile

1. Introduction

Access to digital information is changing people's lives and the world of business, often radically. Technological developments to come promise changes at least as dramatic as the changes to date. The possibilities of the Internet, the World-Wide Web, Moore's law [1], mobile technologies and the Internet of Things will continue to enable widespread changes.

The impact of digital information can be very large. Social media have changed the ways in which people interact. Many of us have experience of online sales, supported by analytics that predicts what we are likely to buy (think of the recommendations created by online retailers). Businesses in all market sectors are taking advantage of digital information but they are also threatened by it. Fundamental changes to business models are underway through concepts like the sharing economy [2]—think of examples like Uber, competing with taxi businesses, and Airbnb, competing with hotels.

But it isn't just businesses that are affected. Lack of access to digital information affects people's ability to make a success in the world. This has been called the "digital divide" [3] and is the focus of government policy in different countries (see, for example, [4]).

These examples show that taking advantage of digital information is important but may be difficult. This paper examines the relationship between digital information and value and shows how to strengthen the link using ideas from the Model for Information (MfI) developed in [5,6]. Digital information changes some fundamental characteristics of information and how it is used—the paper analyses these relationships and shows how the relationships can be reconfigured to take advantage of digital information.

Section 2 summarises some of the key ideas in MfI. Information-processing entities exchange information through interaction so they are called interacting entities (IEs). People, animals, computer systems and organisations are all examples. The information they exchange is in the form of information artefacts (IAs) that include speech, documents, gestures, alarm calls, computer messages and so forth.

A range of selection pressures (including natural selection, market selection and others [5] culminating in what has been called Digital Darwinism [7,8]) has led to the creation of information ecosystems (just "ecosystems" where the context is clear). Each ecosystem has its own conventions for the use of information. English speakers can communicate in English with each other but not always with non-English speakers. Healthcare computer systems exchange information using healthcare system protocols that cannot be interpreted by other systems. Mathematicians can communicate with each other in a form that is incomprehensible to non-mathematicians.

Digital information changes attributes of information including information quality, information friction and type. Information quality has been discussed widely (see, for example, [9]). In [10], the authors were among many to talk of the frictionless economy, capitalism or information. The type represents the degree to which information supports decisions and how it relates to past, present and future events and actions. Current uses of analytics technologies demonstrate different types, in this sense, and include descriptive analytics (about the present and past), predictive analytics (about the future) and prescriptive analytics (which prescribes the action to take based on the prediction).

Section 3 contains a discussion of digital information and how it impacts these elements and their relationships. Difficulties are caused by the relationship between the pace of digital change and ecosystem conventions. On the one hand, ecosystem conventions inhibit the adoption of digital information. On the other hand, some IEs (people and organisations) find it difficult to keep up with changes in ecosystem conventions; this causes a "digital divide" for people [3] and less market success for businesses [11]. For people, ecosystems are age-related—"digital natives", "digital immigrants" and "digital foreigners" [12] differ in their approach to the use of digital information. Digital natives are likely to use smartphones and other electronic media as a routine part of their life and so these tools are part of their ecosystem.

Armed with this analysis, Section 4 shows how to establish the link between value and digital information. This link draws on well-established techniques in organisations (for example, performance management and organisational change management). However, these techniques alone do not make a detailed consideration of the complete range of factors and do not always fully recognise the impact of digital information. The approach introduced in Section 4 links them all together.

2. Summary of the Model for Information

This section describes the main ideas of the Model for Information (MfI) discussed in [5,6]. Computer systems modelling techniques highlight both the functional attributes of systems (the behaviour of a system) and the non-functional (the qualities of a system—like performance, availability, scalability, maintainability). The relevant non-functional attributes of information are information quality (just "quality" when the context is clear), information friction (similarly "friction") and type. Quality is discussed at length in [6]. Friction (discussed in [5]) is a measure of the resources needed for some information-related task—it measures the opposite of efficiency. Large reductions in friction are responsible for the majority of technological improvements associated with information. The type relates to the relationship between the IA and decisions made by an IE. There are three types: descriptive, predictive and prescriptive. Descriptive IAs relate to the current or past state of the environment; predictive IAs relate to the future state; prescriptive IAs provide instructions for action.

In the natural world, evolution has driven the creation of numerous ecosystems. A similar situation exists with respect to information and a range of selection processes. In each case there is a set of conventions that apply to relevant IEs and what they are communicating. The scope of these conventions includes the following:

- the symbols that are used;
- the structure of IAs and the rules that apply to them;
- the ways in which concepts are connected;
- the ways in which IAs are created and parsed (embodying the rules for creating any compatible IA);
- the channels that are used to interact.

Each of these elements co-evolves with the others. We can define an information ecosystem (just "ecosystem" where there is no ambiguity) to be the set of IEs, IAs and channels that support such a set of conventions.

Ecosystems have three elements that are changed by digital information. Information sources (like web sites, computer databases, (physical) libraries, your own memory, other people's memories and the collective memory of a group of IEs) provide ecosystem IAs. Channels provide the communication mechanisms for the ecosystem. These may need new access devices (like smartphones with a suitable browser, for example). Finally the IEs that make up the ecosystem may change (one of the implications of the Internet of Things is a large increase in the number of IEs).

To understand the full impact of digital information we need to consider the relationships between these elements and with digital information. Figure 1 shows these relationships which are described in the following sections.

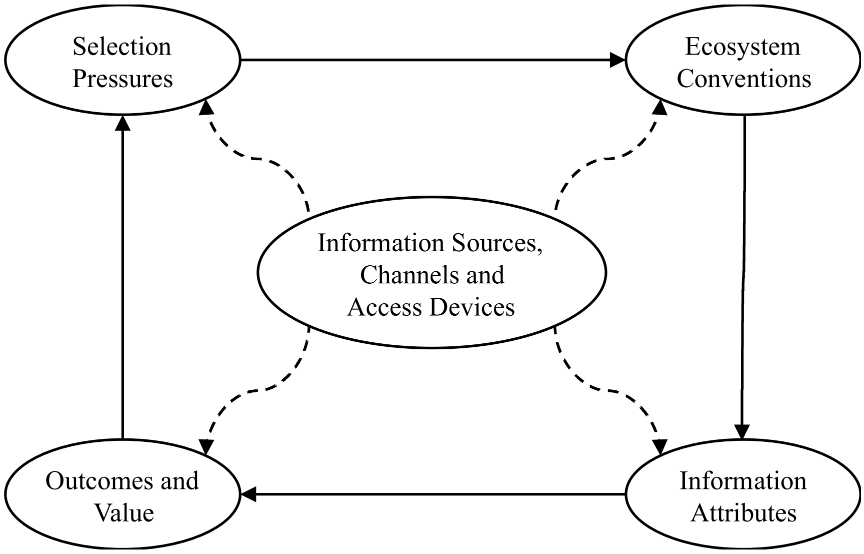

Figure 1. The Factors Affected by Digital Information.

2.1. Selection and Ecosystem Conventions

The top leg of Figure 1 relates selection pressures to ecosystem conventions. Over time, ecosystems establish conventions for generating, consuming and processing information that, generally, create favourable outcomes. These conventions are embedded in the ways that IEs work and develop over time. They constrain the ways in which IEs interact and establish norms for information attributes. The conventions include, for example: the processes used within organisations for achieving tasks; validation embedded in computer systems; and the scope of data models used in computer systems (which constrain, for example, the coverage of IAs produced by the system). As these examples show, some ecosystem conventions may be captured and standardised in computer systems.

There are several factors at work. First of all, selection pressures drive a trade-off between improvements in friction and quality. Other things being equal, an increase in quality will generate more favourable outcomes. Similarly, improvements in efficiency (caused by a reduction in friction) will generate more favourable outcomes. But the two factors are not equivalent. Improvements in quality may have an impact on longer-term outcomes than improvements in friction. For example, the effects of cost-reduction can be felt almost immediately by organisations. Improvements in friction may be obtained with a reduction in quality and vice versa.

There is also a more insidious effect when human beings are involved—they are not naturally good at understanding information quality. Some research in psychology is summarised by Kahneman in [13]. He describes two modes of thinking he calls "System 1" and "System 2". As he puts it:

> System 1 operates automatically and quickly, with little or no effort and no sense of voluntary control. System 2 allocates attention to the effortful mental activities that demand it, including complex computations.
>
> System 1 has biases, however, systematic errors that it is prone to make in specified circumstances.
>
> —Daniel Kahneman [13]

These biases have a major impact on the way in which we respond to information. Kahneman says:

When information is scarce, which is a common occurrence, System 1 acts as a machine for jumping to conclusions.
System 1 is radically insensitive to both the quality and quantity of information that gives rise to impressions and intuitions.

Finally, ecosystem conventions are linked with the availability and use of information sources and channels. For example, organisations use particular processes and systems to acquire, distribute and use IAs but the difficulty of the challenge is captured in the title of [14]: "If only HP knew what HP knows". Making information available where is it needed is a difficult challenge.

Ecosystems do not exist in isolation and there is often interaction between them. The degree of difficulty (and friction) involved depends on the proximity of the ecosystems. Some pairs of ecosystems are more different than others—this affects the information attributes of interaction between them. In some sense, people and Internet routers have less in common (in terms of information) than English-speaking Physicists and English-speaking Chemists. Table 1 shows some examples.

Table 1. The Proximity of Ecosystems.

Difference	Ecosystem 1	Ecosystem 2
Different IE types. Incompatible IAs.	Internet routers.	English speakers.
Different IE types. Compatible IAs.	Computer systems with English voice recognition and synthesis.	English speakers.
Same IE types. Different symbols.	Greek speakers.	English speakers.
Same IE types. Same symbols. Different combinations of symbols.	Italian speakers.	English speakers.
Same IE types. Same symbols. Some combinations of symbols in common, some different.	English-speaking Physicists.	English-speaking Chemists.

An Ecosystem is linked to a particular form of communication (e.g., a language, Mathematics). Human specialisms (e.g., Medicine, Biology) add their own terminology to produce a specialised version. The proximity of ecosystems can be measured by the size of the intersection of their forms of communication. The specialisation of ecosystems, in this sense, is related to the proximity of ecosystems.

Individual IEs can belong to more than one ecosystem—Table 2 shows an example.

Table 2. IEs and Forms of Communication Examples.

Set of IEs	Form of Communication
English speakers	English language
English-speaking people who work in Finance Departments in any organisation	English-based Finance jargon
English-speaking people who work in a Finance Department in a particular organisation	English-based Finance jargon; organisation-specific jargon
One English-speaking person who works in a Finance Department in a particular organisation	English-based Finance jargon; organisation-specific jargon; Mathematics

IEs communicate with other IEs in different ecosystems. For example, businesses combine different specialisms (e.g., Finance, Human Resources, Marketing, Information Technology) each corresponding to an ecosystem. So the exchange of information between ecosystems is routinely conducted but it isn't always straightforward. Indeed, many difficulties with information stem from the difficulties associated with ecosystem interfaces. People regularly complain about interfaces with computer systems (for example, the difficulties associated with complex information interaction are discussed in [15]). Languages divide people. Computer systems with different data models may not be able to exchange data reliably. Table 3 shows some examples of ecosystem interface difficulties. Since different ecosystems have different conventions it is likely that interaction between them will have higher friction than interactions within an ecosystem.

Table 3. Ecosystem Interface Failure Causes.

Reason	Example
Ecosystem conventions for interaction are broken	Human Information Interaction: a badly designed system or web site that is not readily usable.
Converting between Ecosystems loses quality	Different languages: a conversation between people who do not speak a common language.
Interaction has high friction	Learning Mathematics: teaching Mathematics.
Conventions in one ecosystem do not provide sufficient quality for another because information is re-purposed (*i.e.* it was originally created for a purpose with different quality requirements)	Poor web sites: lack of information about products being sold.

On the other hand, some interfaces between ecosystems may have become part of the ecosystem conventions. For example, a Finance department in any reasonably large organisation uses one or more Finance systems and the use of those systems becomes part of the ecosystem. The same applies to personal use of web sites and apps.

2.2. Ecosystem Conventions and Information Attributes

The next leg of Figure 1 relates ecosystem conventions to information attributes. Friction and quality are discussed at length in [5,6], so consider type. In [16], Floridi divided information into three categories: "information as reality", "information about reality" and "information for reality". These types are related to ideas in linguistics. For example, in [17], Searle describes the following categories of illocutionary speech act:

- assertives, which correspond to information about reality;
- directives, which correspond to information for reality;
- commissives, expressives and declaratives, which correspond to other types of speech act.

In other fields (for example, [18]), the terms descriptive and prescriptive have been used in relation to decision-making. More recently, the terms descriptive, predictive and prescriptive have also been used with respect to business analytics and we can apply these terms to IAs. Descriptive content relates to the current or past environment state (corresponding to Searle's "assertives"). Predictive content relates to particular types of future outcomes. Prescriptive content relates to types of action (corresponding to Searle's "directives").

A connection between these types is at the basis of interaction [5,6]. When interacting, IEs need to recognise the current environment state and, based on evidence from the past and connections with potential future outcomes, decide what to do. So, descriptive, predictive and prescriptive content mark elements of the decision-making process for IEs. The connections between them and the degree to which the connections are reliable depends on the quality of the content.

More generally, the idea of quality can be applied to any subsets of space-time, not just the particular subsets that descriptive, predictive and prescriptive refer to. The English language uses different tenses to distinguish between descriptive and predictive content. Science does not always distinguish and laws like Newton's second law are both descriptive and predictive. Computer languages are generally prescriptive (they are instructions for a computer) but may also be interpreted as descriptive (of the functions of the computer system) and predictive (of what actions it will take). It is the ecosystem context—how it is used, rather than the content itself—which determines the difference.

Business analytics is increasingly able to provide predictive and prescriptive content. Analytics can connect many pieces of information, find correlations as a basis for prediction and prescription and enable connections to be visualized and investigated. People on their own cannot do this because of the volumes of data ("Big Data") involved. The improved connectivity reduces the resources required of an IE to interpret at a comparable level of quality and improves the likelihood of a good quality interpretation.

As well as producing predictive and prescriptive content, analytics can improve the quality of all types of content. The use of large volumes of data can increase coverage, enable finer discrimination of differences and increase accuracy.

Analytics often uses People/Objects/Locations/Events (POLE) models to connect people, objects, locations and events (as the name implies). The models use graphs (often explicitly with graph technology) with POLE elements as vertices and connections as edges. Other analytics techniques, like machine learning, can establish connections between vertices that can be used to make predictions (with a level of probability based on the data). Examples (from one or more information sources) can be matched using some relevant properties and may be used to learn what a good outcome (predictive content) or action (prescriptive) looks like. This approach mirrors the more conventional approach in which the matching and learning is be carried out by people and organisations. However, the analytics approach has the merit that it can handle very large quantities of data and provide a solid evidence base.

2.3. Information Attributes, Outcomes and Value

For particular IEs (e.g., people, businesses) particular outcomes may have a value (in a financial sense) associated with them (for example, when you buy something online). Value corresponds to one or more properties of either the IE in question or another IE (for example, the retailer). Corresponding to the value is the cost of delivering the outcome. The cost is represented, in information terms, by friction.

Any outcome will follow from a decision made by an IE that, in turn, is related to the interpretation of IAs processed by the IE. In each case, poor quality means that the preferred action (leading to the most favourable outcome) is less likely to be chosen (descriptive and predictive content) or implemented effectively (prescriptive content).

2.4. Outcomes and Selection Pressures

For any IE, an interaction may increase or decrease the resources available to it. Friction consumes resources and quality and the information type contribute to the outcome and the resources it may provide (or consume). The resources available to an IE have an impact on its ability to cope with selection pressures. For example, businesses need to sell to customers and negotiate good deals with suppliers to make money. Animals need to find food and mates through a series of interactions.

On the other hand, outcomes caused by one IE may change selection pressures for others. Think of love triangles or competition for limited food supplies. So, any interaction can have an impact on both the IE in question and selection pressures for that IE and others.

3. The Impact of Digital Information

Section 2 describes a steady state—when the overall system has settled and ecosystem conventions that are good enough have developed. But, in many cases, digital information disrupts these conventions. Difficulties are caused by the relationship between the pace of digital change and difficulty of changing ecosystem conventions (this has been called "Digital Darwinism" [7,8]). On the one hand, ecosystem conventions inhibit the adoption of digital information. On the other hand, some IEs (people and organisations) find it difficult to keep up with the changing conventions. For people this causes a "digital divide" [3] as some people lose access to services. This problem is significant enough to be addressed by government policy (see for example, [4]).

Digital Darwinism impacts both individual businesses and whole market sectors. Effective use of online sales, analytics and digital engagement (through social media, for example) gives businesses a market advantage and increased profit [11]. At a deeper level, digital information enables fundamental changes to business models through concepts like the sharing economy [2]; examples include Uber and Airbnb in which digital information provides a more efficient of sharing resources (taxis or rooms in these examples). Digital information and, in particular, huge reductions in friction open up a new range of economically feasible possibilities.

Business is driven by business cases that relate cost and benefit. Cost is directly related to friction. Information quality is linked to benefit because improved information quality improves decisions and outcomes. Changes in information type affect both cost and benefit. So, changes in friction, type and quality can affect both cost and benefits.

These developments involve the following three kinds of change: new channels or changes to channels (for example, faster mobile access); new or changed information sources (for example, new web sites or social media sites); changes in the composition of ecosystems themselves (for example, the new IEs which the Internet of Things will introduce).

This section examines the impact of these changes on the state described in Section 2 (see Figure 1). The changes are illustrated with an example based on the rail industry. Tracks need maintenance but track condition is based on a complex range of factors including usage, the ground on which the track is laid (and the factors which affect its stability) and environmental conditions (drought can dry out the soil and rains which can cause erosion).

But first: what is digital information?

3.1. What is Digital Information?

The question "what is digital?" is a subject of philosophical debate discussed, for example, in [16]. The fundamental characteristic of digital information is that it can be converted easily between formats. So, an IA is digital if it satisfies the following two conditions:

(1) its content is discrete (*i.e.* symbolic) not continuous [5];
(2) the representation is independent of any physical entity (in the sense it can be converted between formats reversibly and duplicated accurately at a distance with reasonable friction).

The current conventional format that satisfies both of the conditions is a representation in bits that can be manipulated electronically. For the rest of the paper, that is the interpretation used.

3.2. Digital Information Attributes

The development of the Internet has led to an explosion of information sources. This section examines the impact of this explosion on information attributes. Digital technology enables many possibilities for connecting IAs—the World-Wide Web provides a large-scale example. Computer databases are also connected internally and some (e.g., graph databases) provide explicit modelling of connectivity.

Information attributes are set by the derivation of IAs including the influence of different ecosystems (as described in Section 2.2 above). The impact of derivation is described in [6] but, in general, derivation strips an IA of its context. The IA may have associated meta-information but a digital IA has no associated physical entity (which may provide additional richness). The derivation of an IA may not be clear; differences between the derivations of different IAs may also not be apparent.

The derivation of digital information is different from the derivation of analogue information and the difference affects the attributes of the IAs. Table 4 compares the impact. Of course, in a specific case the impact may be different but, generally, the characteristics of the differences in derivation imply differences in attributes.

Table 4. Comparison of Digital and Analogue Derivation.

Attribute	Digital *vs* Analogue Derivation
Friction	Changes in friction form the major difference between digital and analogue derivation. For some decades these changes have been driven by Moore's Law [1] and have provided large reductions. Many new channels and access devices enable access to a very wide range of IAs with very low friction.
Type	Digital technology provides completely new tools and information sources for creating and storing descriptive, predictive and prescriptive content.
Quality	Digital derivation makes the preservation of quality much easier than analogue derivation because there is a much higher probability of exact replication of content. Timeliness is directly affected by the reduction in friction associated with digital derivation. Timeliness can be improved significantly by digital derivation.

Improvements in technology have seen a large reduction in friction. Two centuries ago sending a message to the other side of the world required a ship; now we can send an email. The implications of this are three-fold. The same activities can be carried out using fewer resources and/or faster (as in the ship example); previously impossible activities can be carried out (many functions carried out by computer systems fall into this category); and the reduction in resource usage frees up IEs to expend their effort on other activities (not necessarily related to information). These changes improve the likelihood of more favourable outcomes (and hence value). On the other hand, very low friction enables more frequent interaction with digital information, often with the attendant difficulties that Kahneman [13] indicates because of the limitations of his System 1.

Interfaces with digital information can often cause difficulties. For example, the interaction between people and computer systems has long been a subject of study (under a whole variety of titles over the years including: Human-Computer Interaction (HCI), Computer-Human Interaction (CHI), User Experience (UXP), Human-Information Interaction [15]). Table 3 (above) demonstrates how quality can be affected at ecosystem interfaces. Digital information is stripped of its context and of the conventions that apply to normal human discourse so the cues that people are used to are not apparent.

The World-Wide Web shows how digital information can increase connectivity. The advent of "Big Data" and the tools to support it (e.g., graph technology) mean that analytics can be applied to, and form connections between, larger sets of data than previously. As a result, decision-making can become more directly evidence-based and insights can be identified which are inaccessible to humans without the aid of such tools.

Consider some uses of digital information in our example. Suppose that relevant data (track condition, the condition of the ballast on which the track is laid, ground conditions, environmental history) were consolidated and geographically aligned. This step would improve the quality of descriptive information. Suppose also that the various conditions were analysed to help understand their effect on track degradation and the requirements for maintenance. This step would improve the quality of predictive information. Finally, suppose that all the data could be visualised on the web, including through mobile devices. This step would reduce friction for engineers who need to access the information, often from different locations. Then, as a result, this digital information could be used to plan maintenance more accurately, minimise unnecessary maintenance, improve the analysis of the root causes of track problems, reduce the requirement for emergency maintenance and improve the efficiency of the management of maintenance.

3.3. Digital Information, Outcomes and Selection

For IEs that consume it, the impact of digital information is widespread, affecting the pace and nature of interaction with the environment. This change has been dubbed "Digital Darwinism" [7,8] and is caused by fundamental changes to selection processes. Digital information enables the same outcomes to be achieved in new ways with reduced friction, new outcomes to be achieved and a faster rate of change of the environment and a consequent requirement for IEs to increase their rate of response to the environment.

Digital information provides the possibility of different approaches to deriving IAs. Digital channels (e.g., over the Internet) may be used to transfer information and new digital information sources (e.g., those provided by the World-Wide Web) may be used.

The degree to which this is an improvement depends on the factors shown in Table 4. There are likely to be substantial reductions in friction once the digital information sources are in place, but there may be a substantial cost in providing them. The impact on quality depends on the various ecosystem conventions and interface difficulties. For example, the Internet offers many sources of news that do not have the same standards and conventions as traditional print journalism.

The increased availability of predictive and prescriptive information provides a short cut for IEs. Before digital information, ecosystems provided descriptive, predictive and prescriptive content in a number of ways (e.g., conversation with knowledgeable people, science) but those approaches can now also be supported by analytics. Analytics may deliver both friction and quality improvements.

In addition, new information sources and channels with low friction and the ability to connect better quality descriptive, predictive and prescriptive information provide opportunities for new outcomes (and value). Online shopping provides an example.

The factors described above provide the possibility of increased interaction and the faster achievement of outcomes. More frequent interaction means more frequent changes to the environment state. For any IE, the interactions of other IEs may affect the possibility of favourable or unfavourable outcomes (including value) so there will be selection pressure for IEs to understand the environment state more frequently and to be able to respond more quickly.

So, the availability of digital information requires IEs to respond to the environment faster. For example, in the software engineering community this need for responsiveness has driven the implementation of agile methodologies, summarised in the Agile Manifesto [19]. One of the principles enunciated in [19] is the following:

> Welcome changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage.

This approach has been adopted very widely. For example, the UK government Digital by Default Service Standard [20] includes the following:

> Build the service using the agile, iterative and user-centred methods set out in the manual.

In order to be more agile, IEs need operate with the level of responsiveness required (agile software development methodologies are an example of this for organisations). But ecosystem conventions may constrain what is easy to achieve (compare waterfall methodologies [21], for example).

In our rail example, the selection pressures are linked to cost (the efficiency of maintenance) and its effectiveness in keeping the track well maintained (and as a consequence reducing any impact on passengers and freight). Both of these are linked to pace and access to the right information at the right time to make decisions. The right time, in this case, is driven by track condition information (of which the quality is improved by the digital predictive information) and access by engineers (improved by reductions in friction).

3.4. Digital Information and Ecosystem Conventions

The ecosystem conventions in our rail example relate to the various processes concerned with track maintenance and how those processes relate to digital information. For example, the engineers will have access to integrated information through a mobile device rather than disparate, uncorrelated information held in different systems and accessible only in particular locations. To change the conventions in this case, the engineers will need to be trained to use the new mobile devices (that also should be designed with a user interface that minimises friction).

This example also illustrates another ideal for changing ecosystem conventions. Once they are familiar with the new approach, engineers will see how digital information will improve their own personal outcomes. So, the selection pressures for the engineers (as IEs) will be aligned with selection pressures for the track maintenance organisation as a whole.

More generally, "digital natives", "digital immigrants" and "digital foreigners" [12] differ in their approach to the use of digital information. Digital natives are likely to use smartphones and other electronic media as a routine part of their life. In these cases, the relevant ecosystem has extended its conventions to include use of those devices and information sources.

Digital immigrants do not necessarily have the same facility with new technology—ecosystems take time to adjust to changes. Ecosystems conventions are based on the existence of particular channels and information sources and when there are changes, there is a time lag before selection processes change the conventions (the duration depends on the selection processes). The old conventions in use during this period may not provide information at the pace needed with the optimum quality and friction. This is the challenge of Digital Darwinism, so what can be done about it?

4. Connecting Digital Information and Value

In this section we consider the question: how can an IE (for example, a person or business) tackle Digital Darwinism and take advantage of digital information to improve outcomes (and value where relevant)? Section 3 highlights the challenges of adapting to digital information. Digital information can be used to improve outcomes (including those involving value) but to achieve this there are three difficulties to overcome: increasing the pace of response to the environment; using new information sources, channels and devices; overcoming existing ecosystem conventions where they are inappropriate and implementing new ones. Figure 2, adapted from Figure 1 shows what is required.

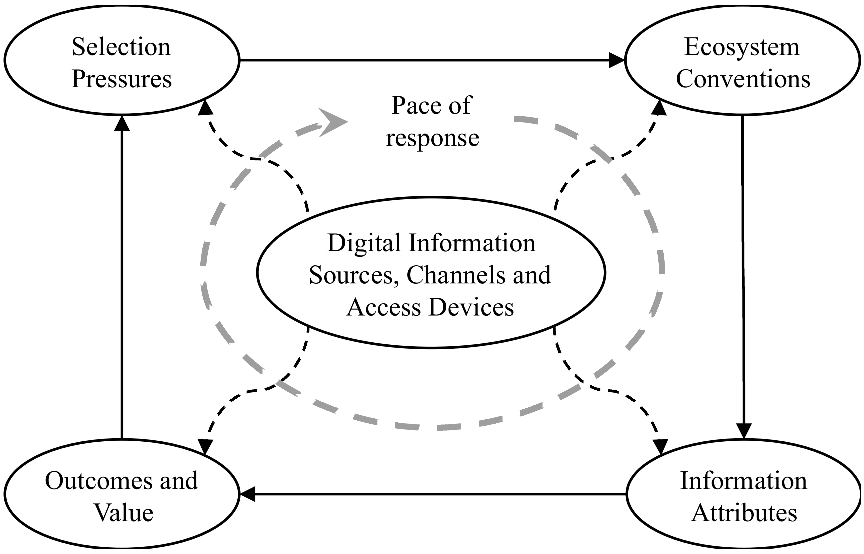

Figure 2. Pace of Response to Selection Pressures.

The approach depends on answers to the following questions:

- what IAs are needed to support the decisions required about outcomes (including the requirements for quality, friction and type)?
- what interactions are needed to meet the increased requirement for responsiveness?
- how can the IAs be derived (possibly requiring additional information sources, channels and devices)?
- what are the risks to the required friction and quality in these derivation routes (including risks from ecosystem conventions and ecosystem interfaces)?
- how can the IE be changed to incorporate these IAs and routes, and how can the changes be sustained with the right pace of response to the environment?

The sections above demonstrate that digital information changes friction, quality and the availability of IAs with different types. The relationship with friction and connectivity are straightforward but the relationship with quality is not. Changing information sources may increase friction but also reduce quality.

The difficulty with the rate of change of digital information is that changes are made before there is time for selection pressures to establish the trade-off. Especially because people do not intuitively understand quality [13], short-term improvements in friction may be made without an understanding of the impact on quality.

Therefore, to make changes it may be necessary to change both the IE and selection pressures (or, at least, those selection pressures which it is possible to change). There are well-established techniques in organisations to achieve this. Performance management (see, for example, [22]) is a term that covers one type of selection pressure applied to people and organisations. When the IE is part or all of an organisation, organisational change management (see the review, for example, in [23]) provides a set of techniques used to change the IE. Systems development provides another set of techniques. With respect to digital change specifically, [11] discusses the techniques required.

IEs recognise properties of the environment (which may correspond to IAs), make decisions and act based on an evaluation of the options. It may be possible to base elements of this process on IAs from digital information sources including descriptive, predictive or prescriptive information. New information sources and channels with low friction and the ability to provide better quality descriptive, predictive and prescriptive information provide opportunities for new outcomes (and value).

These outcomes will be achieved through a set of interactions with the environment and will have a higher likelihood of success if they match the increased pace of response required by the selection pressures. These interactions will require corresponding IAs with a required level of quality.

The IAs will be provided from various information sources through a number of derivation routes. Each route will have its own friction and trade-offs may be required between friction and the potential achievement of outcomes.

The required interactions may change the "non-functional requirements" of the IE. As is the case with computer system architecture, non-functional requirements can only be delivered by certain IE structures. The non-functional requirements, friction requirements, processing, interaction and acquisition may be inconsistent with the capabilities of the current IE. Underlying the changes may be difficulties caused by ecosystem conventions and ecosystem interfaces (as discussed in Section 4)—these difficulties will be revealed through an analysis of the ecosystems and their interfaces. For example, the use of agile methodologies [19] does not fit with a traditional waterfall software development structure [21] so to deliver software faster will require a different approach. More widely, it has been recognised that IT organisations need to support agile implementation alongside more traditional approaches—the term "dual-speed IT" is used for this idea in [11].

Providing the required IE capabilities will provide a starting point but selection pressures, implemented through interactions, will steer the subsequent development of the IE. In some cases (for example, when the IE is part of an organisation) it may be possible to change the selection pressures by changing interactions.

Table 5 shows these activities in more detail. Following these activities enables IEs to use digital information to support the achievement of more favourable outcomes, including those that deliver value.

Table 5. Activities for Connecting Digital Information and Value.

Activity	Description
1. Selection pressures	Understand the selection pressures including the nature and pace of interactions required.
2. Outcomes	Define the desired outcomes and value by: • reviewing available sources, and their information types, friction and quality; • identifying opportunities and assumptions.
3. Interaction	Specify the required interaction patterns including: • the channels and access devices; • combinations and frequency of interaction; • the IAs required (including type); • the quality and friction in each case; • the non-functional requirements of the IE.
4. IA derivation	Define how IAs should be derived including: • the sources of information; • the derivation route; • the required quality and friction for each derivation route.
5. IE pattern	Implement the IE capabilities required to meet the interaction and derivation approach.
6. Selection pressures	Establish (to the extent possible) the selection interactions (initiated from the environment of the IE) required to support the delivery of the desired outcomes once the required IE capabilities are implemented.
7. Development process	Implement the initial selection pressures required to support the development of the IE towards the desired IE pattern by: • identifying the barriers to change including an analysis of changes in ecosystems and new ecosystem conventions required; • establishing the selection pressures required on elements of the IE to implement the new conventions.

5. Conclusion

New digital information sources and channels, supported by the development of analytics, provide opportunities for IEs (e.g., organisations and people). But they cannot take full advantage if ecosystem conventions change too slowly. Digital information changes selection pressures and "Digital Darwinism" demands a faster, more digital, response from IEs.

For organisations, digital information enables new business models and improvements to existing models. For people, the change in ecosystem conventions has created a "digital divide" separating those with good access to digital information from those without it.

To take advantage of digital information requires an understanding of the way in which it affects selection pressures, ecosystem conventions, information attributes (friction, quality and type) and outcomes and value. A combination of reductions in friction, improvements in quality (e.g., through the use of analytics) and a change in the type of information (e.g., through the use of analytics) promise increased value. But these possibilities will only be realised if inappropriate ecosystem conventions can be removed and new ones instated. The approach taken in this paper shows how to do this and how to link digital information and value effectively.

Conflicts of Interest

The author declares no conflict of interest.

References

1. Moore, G.E. Cramming more components onto integrated circuits. *Electronics* **1965**, *38*, 114–117.
2. Hamari, J.; Sjöklint, M.; Ukkonen, A. The Sharing Economy: Why People Participate in Collaborative Consumption. *J. Assoc. Inf. Sci. Technol.* **2015**, in press.
3. Norris, P. *Digital Divide: Civic Engagement, Information Poverty and the Internet Worldwide*; Cambridge University Press: New York, NY, USA, 2001.
4. Government Digital Inclusion Strategy, 2014. Available online: https://www.gov.uk/government/publications/government-digital-inclusion-strategy/government-digital-inclusion-strategy (accessed on 5 November 2015).
5. Walton, P. A Model for Information. *Information* **2014**, *5*, 479–507.
6. Walton, P. Measures of Information. *Information* **2015**, *6*, 23–48.
7. Schwartz, E.I. *Digital Darwinism: 7 Breakthrough Business Strategies for Surviving in the Cutthroat Web Economy*; Crown Business: Danvers, MA, USA, 1999.
8. Bughin, J. Brand success in an era of Digital Darwinism. *J. Brand Strategy* **2014**, *2*, 355–365.
9. Huang, K.-T.; Lee, Y.W.; Wang, R.Y. *Quality Information and Knowledge*; Prentice Hall: Upper Saddle River, NJ, USA, 1999.
10. Gates, B.; Myhrvold, N.; Rinearson, P. *The Road Ahead*; Viking Penguin: New York, NY, USA, 1995.
11. Westerman, G.; Bonnet, D.; McAfee, A. *Leading Digital: Turning Technology into Business Transformation*; Harvard Business Review Press: Cambridge, MA, USA, 2014.
12. Prensky, M. Digital Natives, Digital Immigrants Part 1. *On the Horizon* **2001**, *9*, 1–6.
13. Kahneman, D. *Thinking, Fast and Slow*; Macmillan: London, UK, 2011.
14. Sieloff, C.G. "If only HP knew what HP knows": The roots of knowledge management at Hewlett-Packard. *J. Knowl. Manag.* **1999**, *3*, 47–53.
15. Albers, M.J. Human-Information Interaction with Complex Information for Decision-Making. *Informatics* **2015**, *2*, 4–19.
16. Floridi, L. *The Philosophy of Information*; Oxford University Press: Oxford, UK, 2011.
17. Searle, J.R. A Taxonomy of Illocutionary Acts. In *Language, Mind, and Knowledge* (*Minneapolis Studies in the Philosophy of Science)*; Günderson, K., Ed.; University of Minneapolis Press: Minneapolis, MN, USA, 1975; Volume 7, pp. 344–369.
18. Bell, D.E.; Raiffa, H.; Tversky, A. *Decision Making: Descriptive, Normative, and Prescriptive Interactions*; Cambridge University Press: New York, NY, USA, 1988.
19. Beck, K.; Beedle, M.; van Bennekum, A.; Cockburn, A.; Cunningham, W.; Fowler, M.; Grenning, J.; Highsmith, J.; Hunt, A.; Jeffries, R.; *et al.* Manifesto for Agile Software Development. Available online: http://www.agilemanifesto.org (accessed on 5 November 2015).

20. Digital by Default Service Standard, 2015. Available online: https://www.gov.uk/service-manual/digital-by-default (accessed on 5 November 2015).
21. Sommerville, I. *Software Engineering*; Addison-Wesley: Harlow, UK, 2010.
22. DeNisi, A.S. Managing Performance to Change Behaviour. *J. Organ. Behav. Manag.* **2011**, *31*, 262–276.
23. Barnard, M.; Stoll, N. Organisational Change Management: A rapid literature review, 2010. Available online: http://www.bristol.ac.uk/media-library/sites/cubec/migrated/documents/pr1.pdf (accessed on 5 November 2015).