Digital construction: From point solutions to IoT ecosystem

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ARTICLE INFO

ABSTRACT

This paper takes a longitudinal view of literature to explain the current period as disruptive technology drives an evolutionary adaptation of the construction industry in a historical socio-technological process. The authors argue the way Internet of Things (IoT) solutions are conceived as singularly focused "point solutions" undermine future opportunities. An evolutionary view is overlooked because extant literature describes technology in a particular epoch. An ecosystem perspective needs to influence IT strategy as an emerging "digital layer" transcends a smart city and continues to function long after a traditional construction project completes. We describe innovation as a succession of transformational waves in an evolutionary process that is currently manifesting as "Industry 4.0" and changing expectations for the construction industry. The paper concludes by listing emerging trends and warns existing UK construction companies must understand the transformational process they are in and learn how to adapt with a stronger drive for R&D.

1. Introduction

The aim of this paper is to share insights from a literature review that explains the construction industry is in a transformational stage of a larger evolutionary process. In the UK this is known as "Industry 4.0", but a similar version in the USA is known as the "Industrial Internet" and we can also see a version in China emerging [1]. They all seek to bring IT innovation into a world of Process Control Domains and Operational Technology.

Its objectives are:

- Enable a wider view of transformational socio-technological processes in society.
- Establish a necessary link between the evolution of the UK construction industry and the evolution of its context, such as a smart city.
- Distinguish the evolution of "Information Technology" (IT) from the evolution of "Operational Technology" (OT) and the challenges in their convergence.
- Show examples of "IP Addressable" protocols and "non-IP Addressable" protocols to highlight key challenges of IT merging with OT (i.e. Process Control Domains).
- Outline security threat sources and implication for sharable data.
- Explain the implications for an IoT enabled UK construction industry.
- Demonstrate examples of an evolutionary process for technology

being used in the construction industry.
- Build on the realisation we are in an adapting evolutionary process and outline future research directions.
- Form conclusions that help construction companies to reflect on the way they currently view digital transformation.

2. The case for change

The UK Government is grappling with significant challenges that impact the UK construction industry revenue at the same technology is having a disruptive effect:

1. An agenda of "Austerity" causing a "squeeze" on public sector funds and given the UK Government accounts for around 40% of total revenue for this industry [2], this must be reducing the number of major projects as funding is harder to source.
2. The lack of affordable housing is driving social pressures to increase residential house building (e.g. Mortimer [3]). Indeed, house building is currently the main growth area in UK construction output [4].

At the same the UK construction industry also has its own challenges:

3. Twenty-two percent of construction employees are over the age of 50 and 15% are over 60 year old [5]. We see this pattern in other

industries such as the Oil & Gas industry where the "Baby Boomers" of the 1960s reach the end of their working careers and the "Big Crew change" [6] becomes an issue because succession planning has not been managed well. This represents a potentially significant loss of expertise and experience for those companies that have not planned for it. We see a risk hollowing out presenting itself in the construction industry but would be less risky for companies that have embraced digital transformation as new ways of working become possible, such using collaboration tools and "distributed leadership" [7].

4. With Brexit in mind, the Governor of the Bank of England, Mark Carney, warned that uncertainty is holding back investment [8] on a number of fronts which either directly impacts construction through cancelled projects or indirectly through stalled business strategies that could eventually become construction projects.

5. Perhaps even more worrying are claims that Brexit could mean a loss of 8% of its workforce, meaning some 175,000 vacancies [9] might need to be filled, but from where if EU migration is curbed?

From this view of the situation in 2017 faced by the UK construction industry three significant contradictions stand out clearly:

1. The Government needs to build more but for less cost
2. The construction industry needs to deliver more with less skills available
3. The private sector needs to invest in projects (i.e. Increase CAPEX) whilst uncertainty makes the evaluation of Return On Investment difficult to quantify.

These three contradictions are calling for growth and shrinkage at the same time and so represent very difficult challenges to overcome. Given a labour intensive construction industry of today relies heavily on cash flow portfolio, this "squeeze" is most likely to heighten a desire for short term success criteria, the very opposite of what the long term needs for a slow and managed adaptation to new ways of working and a more capital intensive construction industry.

The Farmer Report [10] outlines a case for digital disruption in the UK construction industry. It sees the following "critical symptoms of failure and poor performance" as:

- Low productivity
- Low predictability
- Structural fragmentation
- Leadership fragmentation
- Low margins
- Adversarial pricing models & financial fragility
- A dysfunctional training funding & delivery model
- Workforce size & demographics
- Lack of collaboration & improvement culture
- Lack of R&D & investment in innovation
- Poor industry image

This is set against an industry which is not applying for billions of pounds of R&D Tax Credits, set up by the UK Government to stimulate innovation [11]. The authors believe that the "case for change" has not been accepted by incumbent leaders in the UK construction industry.

This discussion paper draws insight from a literature review and the industrial experience of the authors involved in many different technology led transformation projects in a number of industries such as Defence, Oil & Gas, Manufacturing, FMCG, and Retail. It explores the potential impact of the Internet of Things (IoT) on the construction industry and its customers. It warns against the temptation to get locked into point solutions that diminish the ability to extract data from across the construction industry. One only has to think about Alphabet's Smart Neighbourhood project in Quayside, Toronto, Canada, [12] and an overarching "digital layer" across a city, to see new possibilities for the

construction industry to extend its role in the built environment with data driven services.

It is important to recognise a recurrent theme which is not explicitly called out in the literature that comprise a series of technology epochs. An underlying pattern reflects an evolutionary process between technology and society, each shaping the needs and expectations for the other. By seeing our current position in the context of an evolutionary process we can begin to glimpse emerging trends [13].

The search for new opportunities begins by recognising technology as a key disrupter of societies over thousands of years so that what is happening today is viewed as a "natural" progression humanity has experienced many times before.

With billions of low cost sensors becoming available, data will flow from "information blind spots" to augment and improve decision making. This focus on sensor networks, especially wireless sensor networks, is what is typically referred to as "The Internet of Things". A "thing" being an object that has a sensor on it or in it, within a transcending heterogeneous computing "ecosystem".

We argue that a key step for construction companies is to recognise a "planned IoT ecosystem" has a long term advantage over trying to combine many "point solutions". By ecosystem we mean an integrated "layer" of hardware, software, connectivity, and information flows linked to key decision making activities. This "layer" is much wider than the construction industry itself and includes all industries that play some kind of role in a continually adapting built environment such as a smart city. This definition is necessary to show a glimpse of future states a construction industry of today will need to adapt towards, or be left behind by new entrants.

By "point solution" we mean an IT offering that has a singular focus on one problem, or one use-case, in a stove pipe type of solution. An example could be a typical Project Planning application used today that is disconnected from what is happening in the supply chain, on site, meteorological risks etc. This "singular" focus usually leads to silo-solutions that make real-time data inaccessible to other solutions.

By understanding we are in a period that has been seen in history many times, we argue that failure to recognise the need to transform will present significant risk to the long term viability of "change resistant" construction companies. In the next section we explain this repeating pattern throughout history.

2.1. We are living in an industrial revolution

The history of humanity can be explained in terms of significant technological impacts. The stone age, bronze age, iron age, steam age, computer age and so on are examples of technological impacts that changed the way society works. Kondratieff explained a cyclic progression of technological disruptions in terms of waves of innovation [14]. What is happening today is itself one wave that is part of an underpinning natural socio-technological evolution.

Probably the most famous wave is the first "Industrial Revolution" but there have been others such as the Deep Plough enabling Northern European countries to grow more crops than they consumed and shifting economic power away from the Mediterranean countries to Northern Europe around 1100 CE [15]. As these technological waves unfold they ripple through many aspects of society, and disrupt established power structures leading to new institutional governance frameworks designed by incoming agenda (e.g. The emergence of labour markets, wages and rents as feudalism and serfdom gave way to the economic prowess of emerging of towns and cities such as Norwich and Newcastle in the 1300s).

Some in Europe are calling this current wave of IT innovation the Fourth Industrial Revolution, or "Industry 4.0", and in North America, the "Industrial Internet". We see these as labels attached to a deeper technological evolution of what we typically call "The Internet". This paper argues a combination of digital innovations collectively called the Internet of Things (IoT) will bring new emergent needs and