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Offsite Sustainability—Disentangling the Rhetoric through Informed Mindset Change

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Abstract: The construction sector and concomitant supply chain has been acknowledged in the literature as a major contributor to environmental "stress", from the design, sourcing and extraction of raw materials through to transportation, design, construction and demolition. Clear indicators/solutions have been showcased as vehicles for reducing this stress, ranging from lifecycle costing through to waste reduction strategies, carbon assessment and "green" environmental assessment tools to name but a few. However, this paper argues that whilst some of these (intervention strategies) may have had some positive effects, the main challenge rests with people—inter alia, the key decision-makers and leadership structures with the "position power" to effect change. Acknowledging this as a supposition, this paper uses three discreet construction organisations engaging in offsite construction as a micro-study (cf. cross-case study) to evaluate sustainability perceptions. In doing so, it focuses specifically on sustainability practices and business processes underpinning technology (adoption, absorption and diffusion), including the perceptions of different stakeholders involved in each of these three companies. In total, 30 respondents from three organisations (cases) participated in this study, representing three tiers of management (top, middle and first line). Priority areas are highlighted, along with the reasons supporting these perspectives. Findings from this work present a new technology diffusion sustainability model for offsite construction. This model identifies sustainability causal links, super catalysts, actuators, barriers, forces and facilitators. More importantly perhaps, this work presents a clear case for "conjoined thinking" in order to instill a collective mindset change and common purpose for those wishing to evidence offsite sustainability.

Keywords: offsite construction; sustainability; technology adoption; organisational capabilities; organisational change

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1. Introduction

World population growth has not only accelerated economic development but also created an increased demand for natural resources—the corollary of which therefore needs to be protected for future generations [1], especially given a predicted population of 11 billion by the end of the century [2]. This resonates with the increasing need for organisations to "take responsibility", through the adoption of new sustainability practices and strategies [3]. This, however, requires organisations to radically review their current business operations in line with transformation measures needed to meet/adopt/embed sustainability concepts into their business model. In preparation for this, there are a number of measurement tools, models and frameworks that can be readily used to start this process. One of these approaches is the Triple Bottom Line (TBL), which was initially introduced as an "accounting framework" to measure the sustainability performance of organisations based on interrelated social, economic and environmental dimensions [4].

Globally, whilst figures vary from country to country, it is widely acknowledged that the construction sector is often seen as a major indicator of economic growth and contributor to Growth Domestic Product (GDP), employing around 7% of the workforce.

Where construction-related spending accounts for around 13% of global GDP in 2020, with an expected growth pattern to be higher than manufacturing or services by 2030 [5]. Given this, it is equally important to note that the sector as a whole was also recognised as a major contributor to greenhouse gas emissions and many other environmental stress indicators. Whilst the sector has addressed some of these challenges through positive action, net-zero strategies and government regulatory enforcement; arguably, these initiatives can only be seen as the starting point of the transformative challenge that is actually needed. On this theme, over the last 20 years or so, there has been increased interest in the use of Offsite Construction (OSC) and Modern Methods of Construction (MMC), particularly as a real lever for change—to transition away from the problems (cf. quality, cost, waste, energy, etc.) typically associated with "traditional" construction [6,7]. More importantly perhaps, is their perceived ability to support wider initiatives such as circular business models [8,9].

From a business perspective, it is generally accepted that information and communication technology (ICT) plays an important "enabling" role, evidenced by many exemplars [10,11]. This was also seen to not only support sustainability initiatives per se but also their corresponding sustainable development targets. For example, sustainability performance was the focus of numerous studies, especially in construction [12–14], where the enabling role of technology was highlighted as a significant contributor [15–19]. Acknowledging the strong influence of technology [20–22], equally, there is a fervent need to manage the introduction of this technology into the workplace. In particular, the adoption, diffusion and dissemination process. This is particularly challenging in construction organisations, which are often resistant to change [23,24].

Cognisant of the above, this paper attempts to demystify some of these challenges by investigating the causal connectors underpinning the engagement, deployment and use of technology to improve sustainability performance. In doing so, the work is framed (contextualised) across three mutually independent Architecture, Engineering and Construction (AEC) organisations; using an OSC lens to examine organisational capability against sustainability criteria. The thought process here was to uncover new insight into technology (as a catalyst for change); thereby, identifying the unifying unique organisational capabilities needed to manage the technology adoption/diffusion/dissemination process—ergo, discover a more nuanced understanding of the complex interrelationships involved and their subsequent impact on business and sustainability performance.

The first part of this paper outlines the concepts and theoretical underpinnings of sustainability, technology adoption, diffusion and dissemination. This includes the correlation of the organisational capabilities theory with corporate goals. From this, a conceptual framework is developed for discussion. This highlights technology diffusion capabilities and the organisational dynamics supporting corporate sustainability performance.

2. Historical Challenges

2.1. Corporate Sustainability

It is argued that the origins of sustainability stem from the idea of progress, which concerns the progress of humans starting from pre-modern times to the modern-day [25]. Over these years, the idea of progress, growth and development went through various phases and turned into an expectation of unlimited economic growth [1], where, for example, manufacturing and production across the world increased about 1730 times as a result of the industrial revolution [26]. However, this prospect did not last long, and in the early 1970s a report "*The limits of growth*", estimated that the limit to the growth of the planet would be reached within 100 years [27]. Soon after this report, the United Nations Conference on Human Environment (Stockholm in 1972) emphasised the idea of "defend and improve the human environment for present and future generations" [28]. The term "corporate sustainability" follows this concept in many respects by adopting the mantra of "defending and improving" corporate assets for the "present and future", and was defined as "*meeting the needs of a firm's direct and indirect stakeholders (such as shareholders, employees, clients, pressure groups, communities etc), without compromising its ability to meet the needs* *of future stakeholders as well.*" [29]. On this theme, Elkington [30] described a sustainable corporation as one which "*in the most general terms would not only conserve and use nature and natural resources for the benefit of present and future generations, but also respect a range of human rights—including the right to a clean, safe environment—in the process. And it would contribute to progress against a range of new human welfare indicators which are currently still in development*". These definitions underline the three key elements of corporate sustainability (cf. TBL), ergo: integrating short-term and long-term aspects; consuming the income and not the capital; and incorporating the economic, ecological and social aspects of TBL [29,31].

In its broadest sense, TBL can be seen as a framework for measuring performance, which focuses on economic, environmental and social measures [32]. Where economic sustainability refers to aspects that include cash flow, liquidity and shareholder returns. Environmental sustainability, on the other hand, emphasises the importance, use, consumption and reproduction of natural resources. The third stream of this relationship concerns social measures. These embrace societal impact and wellbeing—adding value to communities, increasing human capital and enhancing social capital [29,33]. The integration of these three dimensions not only provides an "accounting tool" for organisations to measure their performance but also a "strategic tool" for improving their corporate sustainability level [32].

Notwithstanding the opportunities presented through the TBL approach, discourse continues to critique the links and relationships between each bottom line [34]. However, TBL is still seen as a popular approach for assessing and improving corporate sustainability across various industries [35–37]. The main motive behind TBL is to embed sustainability into organisations' business strategies to improve organisational performance across the economic, social and environmental bottom lines. Acknowledging this, advocates have promoted the notion of "upskilling" organisations in order to make them ready for both current and emerging sustainability challenges [38,39]. Cognisant of these needs, recent research has now refocussed these efforts through an organisational capabilities approach. Where the thinking behind this resonates with the need to develop and sustain organisational competence to successfully respond to these sustainability challenges [40,41].

2.2. Organisational Capability

The underpinnings of organisational capability stem from the need to achieve and sustain performance better than the average of the industry; where the term "competitive advantage" started to be used [42,43]. In this respect, the nature of competitive advantage encompasses several theories, including Resource-Based Theory, which examines organisational resources and capabilities as drivers of competitive power [43,44]. Various definitions of resources exist in the literature, from "... all assets, capabilities, organisational processes, firm attributes, information, knowledge, etc." [43], through to " . . . anything which could be thought of as a strength and weakness" [44]. However, the overriding consensus coalesces around the premise that resources have a strong impact on competitive power, and as a consequence, organisations need to manage and organise these resources efficiently and effectively in order to maximise their value [45]. In doing so, an organisation's capacity to deploy resources to achieve business goals and objectives was termed "organisational capability" [46,47].

From an organisational capability perspective, Dynamic Capabilities Theory evolved; which can evaluate capability from multiple perspectives, where for example, dynamic capabilities are seen as an organisation's ability to adapt skills and resources to the challenges and changes needed [48–51]. Whereas, others see this as being less esoteric, focussing on an organisation's capacity to create market change—engaging senior management's ability to sense opportunities and reconfigure resources as a response [52,53]. Notwithstanding these perceptions and positioning, for the purposes of this study, this work adopts the definition of Helfat et al. [54], which describes dynamic capabilities as "the capacity of an organisation to purposefully create, extend or modify its resource base". The rationale behind this resonates with the need to appreciate the context and the corresponding specific capabilities needed to develop, refresh, and renew and its resource base [55].

The increased resurgence and need for sustainability practices has made organisations more acutely aware of the need to manage and govern depleting natural resources; where some of which have used this as a powerful enabler of competitive advantage, regardless of industry [56]. Notwithstanding this, one of the seminal challenges has been to really understand the impact of sustainability capabilities on the business itself, particularly the interaction between sustainability enablers, organisational dynamics and organisational capabilities [57–59]. Some of these issues were examined through: organisational learning and sustainable innovation capability [60]; through unique corporate sustainability capabilities (and measures) aligned to the TBL perspective [61]; or, through integrative frameworks [62], which present organisational capabilities and sustainability drivers/outcomes (Figure 1).

Figure 1. Organisational capabilities of sustainability (adapted from [62]).

Figure 1 presents a central core "Organisational Capabilities for Sustainability", which connects seven tenets (collaborative relationships; absorption of knowledge/learning; flexibility/adaptation; management; marketing/external communication; alignment/motivation; and innovation/technology). Of particular note here is the importance of innovation and technology, especially the organisations' ability to embed these technologies into their organisational and operational processes, as an organisational's capability needs to support sustainability [62]. This is especially pertinent to the foundations of this paper and the argument presented. Moreover, this also aligns with the thinking behind innovation/technology and sustainability—especially supporting the interoperability of innovation capability to enhance corporate sustainability [63]. In this respect, Industry 4.0 technologies can also be seen as enablers of sustainability [64–66], especially technological readiness to support sustainability [67]. In summary, therefore, given the link between capability, technology and sustainability, there is also a need to understand the working environment (OSC) and the corresponding interplay of all drivers involved in the design, manufacturing and construction processes.

2.3. Offsite Construction

The term OSC embraces several definitions, covering different contexts and perspectives [68]—from manufactured construction, off-site manufacturing, modern methods of construction, prefabricated construction, industrialised construction, offsite construction, etc. Where ostensibly, the overarching umbrella term of OSC can be seen as an approach for tackling the inefficiencies of traditional construction methods [19], by moving some of the efforts into a controlled environment to exploit the modern industrial techniques [69,70]. This approach was espoused as being particularly effective at addressing environmental/sustainability, carbon and waste [71,72]; through to quality, process and performance [6,73,74]. The benefits of OSC were highlighted in numerous studies [75,76]. However, it is argued here that AEC is only now starting to realise the benefits of OSC and TBL [77,78]. This increased awareness has focussed efforts to explore specific OSC areas that directly support sustainability, such as: embodied carbon [79]; waste generation [80]; energy utilisation [81]; recyclability [82]; and future adaptability [83].

Whilst the adoption and uptake of OSC can vary considerably from country to country, priorities and trends also vary [7,84]. Some countries seem to be using OSC as a real driver for change; whereas, others seem to reflect on opportunities (cf. the adoption curve) before they invest. In many respects, this is not too dissimilar to early adopters and innovators in other fields.

One of the treatises of this paper was to not only uncover the reasons behind the adoption of OSC per se (cognisant of sustainability benefits, etc.) but to also ascertain whether the technology underpinning these decisions acted as a lever for change or perhaps a mechanism for commercial exploitation. In this respect, Turkey was chosen as the focal point of discussion, given that construction represents 6% of GDP [85] and that several large companies have started to invest heavily in OSC. Moreover, Turkish contractors' international reach and significance are considerable [17,86,87]. Moreover, Turkey was ranked 14th for the export of prefabricated elements, with a value of over 238 million USD [88].

2.4. Technology Diffusion: Theory and Concepts

Arguably, the antecedents of technology diffusion date back to the 19th Century. However, diffusion theories became more popular and prominent among anthropologists [89–91]. Where one of the main social theories proffered by Rogers [92] on "diffusion of innovations" defined diffusion as "the process by which an innovation is communicated through certain channels over time among the members of a social system" [91].

The theory defines the process of innovation decisions as a series of actions and choices through which individuals, groups or organisations evaluate new ideas prior to implementation. In this respect, the diffusion process consists of five main stages: knowledge, persuasion, decision of adoption, implementation and confirmation [91]. From a new technology implementation perspective, of particular note here is the authorisation process, which is typically undertaken at the senior management level [93,94]. However, it is equally argued that this decision should also involve end-users [95–97] as this supports end-user acceptance. Given this, the literature has also examined the complex nature of the technology diffusion process through various prisms, including individual, organisational, environmental and technology perspectives [98–101].

The diffusion of innovations theory was tested, praised, criticised, improved and contextualised by various authors [102–104]. One of the most interesting debates over recent years rests on the premise that "real-life" observations and interactions of diffusion dynamics are particularly challenging through discrete linear approaches (cf. [105–107]). In this respect, circuitous iteration can sometimes influence the ways through which organisations engage in this process. For example, it is argued that almost every part of AEC is reliant on some form of technology. Moreover, these technologies continue to evolve almost on a daily basis—being heavily reliant on digital data [108]. In this respect, organisations are "expected" to absorb and diffuse this technology, which in turn allows them to "transform", and in doing so, deliver greater value [109].

The dynamics of technology diffusion in AEC is not new (e.g., [110–113]). Moreover, given the growing interest in OSC, several studies have now started to uncover new insight and understanding into offsite solutions [114,115].

In summary, therefore, AEC has now reached the stage where it needs to more purposefully focus on intervention strategies, especially given the need to promote and support sustainability through OSC solutions. This requires complex decision making—not only on sustainability practices and business processes underpinning technology per se but also on the adoption, absorption and diffusion processes needed.

3. Research Methodology

The premise supporting the research methodological rationale underpinning this study considered the best possible approaches for evaluating AEC sustainability performance through OSC, using one primary lens (technology) as the prism. In doing so, the assumption here from the outset was that developing organisational capabilities, which specifically enabled/supported and delivered technology diffusion, would in fact act as a catalyst to deliver sustainability. This thinking also aligns with the TBL approach (cf. economic, environmental and social measures). Accepting this as a proposition, the challenge of selecting an appropriate methodological approach and capture instrument, therefore, needed to be nuanced, where subtleties, opinions and viewpoints were considered equally valid to conventional binary responses. For example, it was anticipated that organisational thinking would vary from one company to another; and, more than likely, that the thinking of people within each organisation would also differ from those around them—especially in tiered structures with varying governing levels of authority. This was an important consideration, as the main focus of this work aimed to understand the impact of organisational dynamics on not only the decision-making processes but also the ways through which sustainability-focused technology diffusion capabilities were managed.

Given this, the methodological approach adopted needed to capture organisational behaviour and the thought processes governing decisions. In this respect, it was deemed important to capture evidence through interviews, observations and interactions in order to more fully appreciate the organisational dynamics and cultural nuances associated with the observed environment [116]. Based on this premise, the starting part of this research commenced with the identification of core sustainability parameters that supported the technology diffusion process.

From an epistemology perspective, this research adopted interpretivism as the main lens of discovery. This was considered not only appropriate for interpreting/understanding "meaning", but also for attachments and actions needed to measure and observe phenomena. This resonates with the need to capture actors' perception, experience and understanding of "objective reality". In doing so, this follows the principles of "explicit mixed methodology" [117], which was seen to be particularly effective in increasing research rigour and data reliability [117–119].

The start of this research trajectory commenced with an examination of "sustainability capabilities" [62,120], the remit of which was to define, shape and refine the observational "lens" [121]. In this context, the lens was the fulcrum interface between sustainability principles and the technology diffusion processes. This, by default, included the organisational dynamics and decision-making processes underpinning these, where it was acknowledged that the technology diffusion process ostensibly takes place through social systems and structures [91]. With one or two exceptions, the literature review was confined to publications dating from 1990 to date (2022). This constraint was applied in order to focus on currency, given that the main emphasis of this work needed to determine the main drivers of the technology diffusion process. In this respect, the focus was placed on peer-reviewed journals within AEC, supported by the literature from other fields, including management, social sciences and information systems (IS). This included parameter keys such as "technology diffusion", "technology adoption", "innovation diffusion", "ICT diffusion" and "ICT adoption". Figure 2 presents the process steps of this research.

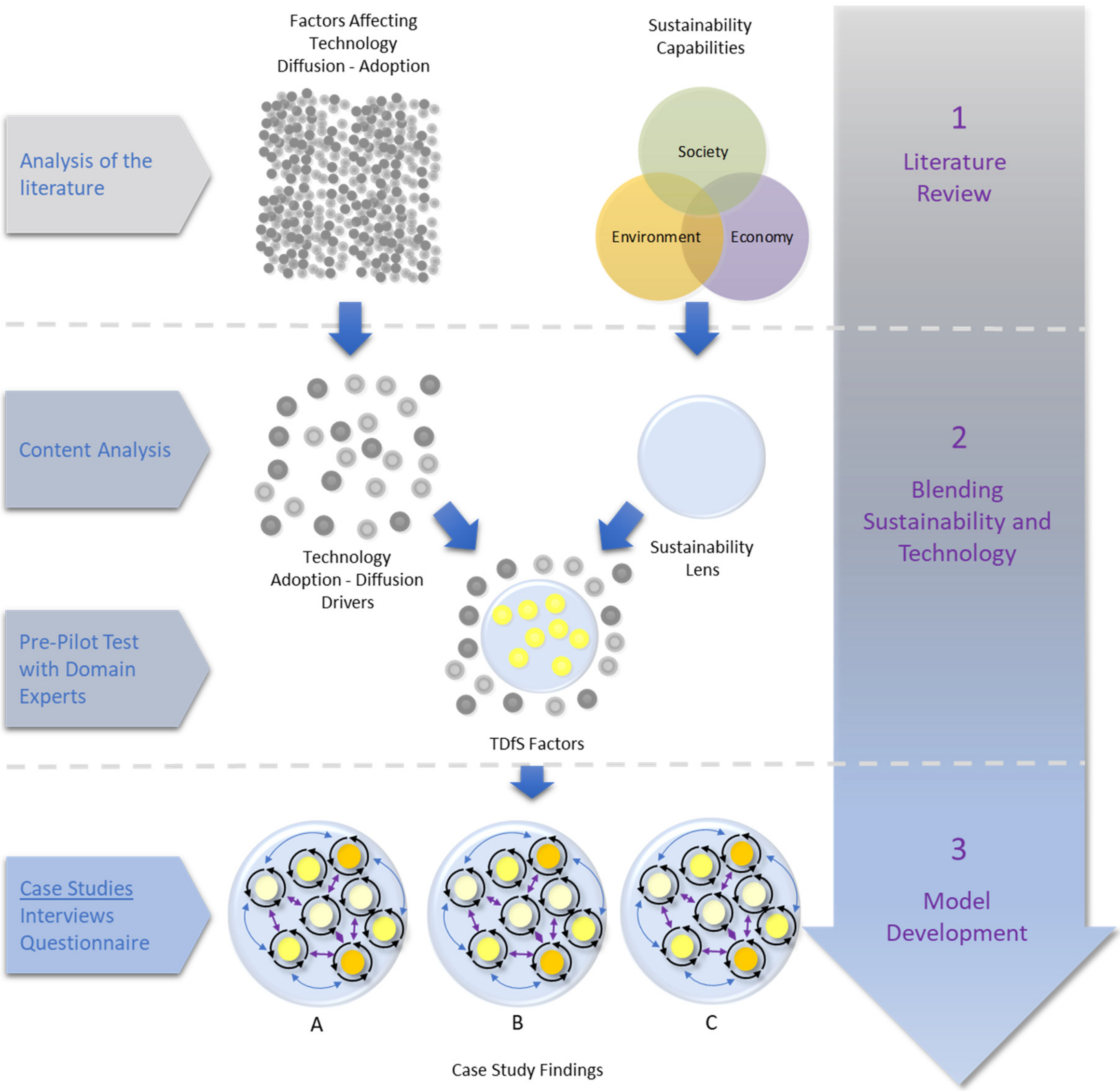

Figure 2. The research process.

Findings from the literature review were then synthesised and distilled by frequency to provide focus—ergo, pattern matching, in order to capture the technology diffusion factors that influenced, shaped or enabled sustainability. Content analysis was used as a filtering lens as part of this process. These findings were then pre-piloted with six construction domain experts with knowledge and experience of: (i) ICT implementation, (ii) sustainability, and (iii) organisation strategy.

These findings then helped inform the type of organisations needed to capture the primary data and in-depth knowledge/understanding required in the decision-making process. In this respect, a multiple case study approach was adopted using three separate case studies. These were chosen through purposive sampling in order to provide "literal replication" [122]. Three case study companies were chosen in Turkey, all of which had extensive experience in offsite and sustainability, with projects ranging from housing to commercial and infrastructure projects (Table 1).

Table 1. Case study profiles.

Profile	Company A	Company B	Company C
Turnover (USD)	750 m	1040 m	700 m
Core Operations	Housing, public service/commercial/industrial buildings and infrastructure projects	Housing, public service/commercial buildings, industrial/power plants, infrastructure projects	Commercial/residential/industrial buildings, power plants, infrastructure projects.
Area of Operation	Turkey, Russia and Middle East and North Africa	Turkey, the Middle East, North Africa, Caucasia and Central Asia, East and Central Europe	Turkey, the Middle East and North Africa

In each of the three case study companies, the perspectives of three management levels (First Line Management, Middle Management and Top Management) were captured, following case study protocol [123], in order to secure a "representative" and balanced view of opinions across this strata. In addition, given the need to ensure "saturation", it was deemed necessary to "purposively" select four respondents for First Line Management, four respondents for Middle Management and two respondents for Top Management for each case. Of particular note here, the choice of selecting only two Top Management respondents was made purely on availability, as at this level, only a select number of respondents were available for selection. Notwithstanding this, Table 2 presents the distribution and corresponding level of experience for these respondents.

Table 2. Distribution of respondents' experience by management levels and company.

Company	Management Level	Experience (Years)					Total NR
		0–5	6–10	11–15	16–20	≥21	
A	Top Management	-	-	-	-	2	2
	Middle Management	-	1	-	1	2	4
	First Line Management	2	1	1	-	1	4
B	Top Management	-	-	-	1	1	2
	Middle Management	-	-	2	1	1	4
	First Line Management	-	3	1	-	-	4
C	Top Management	-	-	-	-	2	2
	Middle Management	1 *	-	2	1	-	4
	First Line Management	4	-	-	-	-	4
Total		7	5	6	4	8	**30**

Nb: NR = Number of respondents; * indicates previous experience in other industries.

From Table 2, all respondents were interviewed using semi-structured interviews in order to capture personal perceptions and experiences. These interviews were manually transcribed and then evaluated through content analysis in order to analyse the rich qualitative data. From this, links and dependencies were evaluated in order to determine the organisational dynamics that enable and support the diffusion process of novel technologies. This process was further complemented by an additional layer of questioning, which was used to not only act as a validity check but also as a mechanism for enriching the answers provided. This used a ranking system where respondents were asked to assess the level of existence of organisational capabilities based on a scale of 1–5 (where 1 = low, and 5 = high). Quantitative data were then used to determine the relative ranking of the criteria based on existence. This process followed the approach of previous studies [124–126]. However, for explicit use in this paper, the term "Relative Existence Index" (REI) was used in order to avoid interpretive confusion. This also helped to better reflect the application context in line with previous studies [117,127,128]. Given this, the REI was determined using the following formula (EQ1), adapted from Chen et al. [127].

EQ1 Relative Existence Index

$$Relative\ Existence\ Index\ (REI) = \sum_{i=1}^{5}(\frac{\omega_i.f_i}{a.n})$$

i = scale anchor point given to each criterion by the respondent (*ranging from 1 to 5)*
ω_i = weight for each point *(rating in scale of points, from 1 to 5)*
f_i = frequency of the point i by all respondents
n = total number of responses
a = highest weight (5 in this study).

Results from the quantitative analysis presented a ranking of existence for the defined criteria. From this, in order to highlight points of priority, criteria were ranked from negative to positive existence. However, due to the limited number of respondents, on some occasions, there were situations where two or more criteria had the same score. In these cases, the standard deviation values were used to determine the overall ranking. Additionally, in situations where the index and standard deviation values were the same, then the arithmetic ranking mean was used to determine the overall ranking.

In summary, therefore, this combined use of an explicit mixed methodological approach was considered robust enough to test arguments and propositions through multiple gateways. The main rationale of this was to try and unpick the main causal issues that affected sustainability performance. This included the thinking behind decisions and the corollary of these on organisational capabilities. The challenge here was to identify the pivotal points which actually enabled and supported the delivery and diffusion of technology—ergo, the main sustainability catalysts.

4. Findings

4.1. Technology Adoption Diffusion Drivers

Technology diffusion was seen as a broad multi-dimensional and multi-layered set of interconnected processes. These connections can be considered as a series of subsystems that are interlinked with each other; where at the highest level of order, "Technology Adoption & Diffusion" embraces three subsets, namely: "Individual", "Organisational" and "Environmental" (Figure 3), making four primary domains in total.

The two-staged literature synthesis was followed by the pre-piloting phase with six domain experts, covering the four primary domains presented in Figure 3. This reflects the main drivers of the technology diffusion process. Where "Technology Adoption & Diffusion" presents the components of technology—including a range of criteria from costs and infrastructure requirements, through to use and perceived benefits. Collectively, this is seen as the nucleus for discussion on subsequent adoption and diffusion decisions. From this, the impact of adoption and diffusion are then considered at the "Individual" level, especially the drivers that affect individual engagement—from use, through to the provision of skills and training needed to ensure this technology is effectively incorporated into organisational systems. In this respect, the "Organisational" domain embraces the organisational dynamics of the company as a whole. This domain is often considered one of the most challenging aspects to manage, as it intrinsically establishes the ways through which technology (and its impact on employees) is governed and managed. This includes a range of parameters that ultimately affect the organisational "behaviour" of technology adoption and diffusion, ranging from organisational culture to leadership and vision. The final domain "Environmental" can be seen as a set of targets or organisational goals linked to its mission statement or raison d'être, which include issues such as client demand, competitive forces, and market dynamics. In summary, therefore, whilst the impact of each of these four domains ultimately governs and shapes how successful technology adoption is managed from an organisational perspective, generating a clear distinction of the subsets from each of these four main domains requires a much deeper understanding of the forces and interconnections (Table 3).

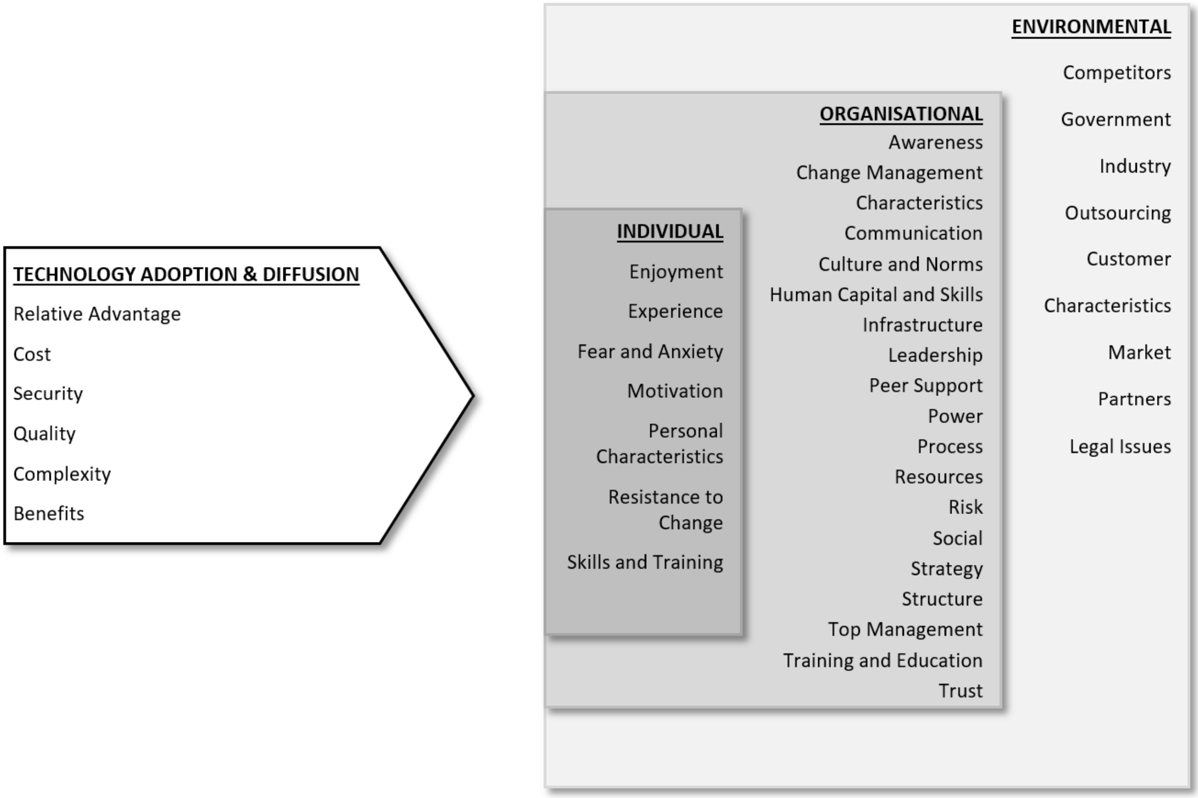

Figure 3. Technology adoption diffusion drivers.

Table 3. Organisational technology adoption and diffusion drivers.

Drivers	Sub Drivers	Cited in
Awareness	external market awareness	[129]
	market analysis and positioning	[130,131]
	internal awareness	[132]
Culture and Norms	attitudes towards computers and tech	[133]
	climate that facilitates innovation	[134]
	cultural resistance	[135]
	culture	[136,137]
	feel pressured to be effective in using ICT	[23]
	group's innovativeness norm	[138]
	individualism	[139,140]
	information-sharing culture	[99]
	long term orientation	[139]
	uncertainty avoidance	[100,139]
	decision making	[141]
	support for sharing ICT experience	[23]
	participate decision making	[142]
	power distance	[139,140]
	power-sharing	[142]
	tolerance for conflicts and risk	[142]
	rewards and recognition	[143]

Table 3. *Cont.*

Drivers	Sub Drivers	Cited in
Leadership	autonomy	[144]
	empowerment of staff	[134,145]
	incentives	[135,146]
	leadership capability	[134,147]
	ownership	[148]
	tangible rewards for sharing experience	[23]
	decision making	[149,150]
Top Management	lack of management support	[138,151]
	ability to work under pressure	[99,100]
	IT knowledge of top management	[129]
	ability to formulate clear strategic motives	[152]
	attitude towards change	[153]
	top management characteristics	[100]
	management effectiveness	[129]
	top management support	[99,154]
	management risk perception	[100]
	management style	[155]
Strategy	ability to formulate clear strategic motives	[152]
	clearly stated, attainable, valuable shared vision	[156]
	firm strategy	[148,157]
	image	[99,151]
	innovation goals match strategic objectives	[158]
	incentive alignment	[151]
	strategic management	[159,160]
	strategic planning	[99]
	strategic role	[100]
Human Capital and Skills	IT experience	[99,129]
	IT expertise of employees	[129]
	IT knowledge of managers	[155]
	skill level of staff	[161]
	problem-solving skills	[162]
	personal IT skills	[155]
Financial	financial capability	[155]
Power	centralised decision making	[163]
	centralised planning and control	[100]
	perceived interpersonal power	[133]
	political risks	[155]
Change Management	innovation champions	[100,155]
	managerial tolerance to change	[164]
Trust	inter-organisational trust	[165]
	trust	[99,166]
Peer Support	supervisor support	[100]
	outside consultants	[129]
	peer support	[146,151]
	peer influence	[138]
Communication	communications (internal)	[167,168]
	communications (external)	[129,169]
	external integration	[99]
Structure	firm size	[152]
	fit between organisational design and type of innovation	[170]
	hierarchical level	[100]
	IS department size	[100,171]
	network externality	[100]
Training and Education	enough time for training	[23]
	flexibility for learning	[23]
	managerial training	[100]
	mentoring support	[23]
	training	[145,146]
	participation in training	[172]

Table 3. *Cont.*

Drivers	Sub Drivers	Cited in
Infrastructure	IS maturity	[100]
	IT infrastructure	[155]
	technology integration	[173,174]
	technology policy	[100,175]
	availability of complementary technologies	[176]
Characteristics	organisation's age	[177]
	organisation's image	[129]
	organisational complexity	[99]
	system openness	[154]
	resilience	[178]
	professionalism	[100]
	organisational readiness	[171]
	org. innovativeness	[179]
	degree of independence	[152]
	competitive environment	[138]
Process	process integration	[100]
	degree of integration	[99]
	backward and forward integration	[134]
	process reengineering	[180]
	process-tech fit	[135]
	process management	[181]
Resources	resources	[148,171]
	organisation commitment (resources)	[23]
Risk	risk-readiness	[162]
	response to risk	[100]
Social	social attitude	[155]
	social network	[146]
	subjective norms	[100]

4.2. *Current Level of Capabilities*

The next stage in this research involved questioning corporate capabilities, especially those that helped the company with technology diffusion to support sustainability. In this respect, 30 respondents were invited to identify the factors that enable Technology Diffusion for Sustainability (TDfS). Moreover, they were also asked to share their perception and understanding of these areas in order to provide a richer and more meaningful insight into these aspects (Table 4).

From Table 4, it can be seen that the top three factors that required immediate attention in order to support an organisation's ability to diffuse and adopt novel technologies were: Rank 1 "Ability to make tough decisions quickly" (0.633 REI); Rank 2 "Staff ability to change work habits as a response to change in the demands" (0.700 REI); and Rank 3 "Ability to analyse the potential risks of change on organisational resources" (0.707 REI). In addition, the mean scores and REI values for these 26 factors emphasised their importance. From this, the factors respondents felt more confident about were: Rank 26 "Ability to improve skills, knowledge, and approach to new technology" (09.20 REI); Rank 25 "Ability to provide technical support from outside of the company" (0.867 REI); and Rank 24 "Ability to provide service and technical support within the company" (0.853 REI).

Whilst Table 4 provides a holistic reflection of the TDfS capabilities and REI rankings, it is important to appreciate the subtle nuances and differences between different managerial levels. In this respect, Table 5 presents the REI values and rankings for all three management levels, where the last column reflects the collective view of 30 respondents in terms of the priority rankings. This also presents a wider diversity and granularity of detail on the views/perceptions of respondents within these three management strata levels. From Table 5, it can be seen that all three levels agreed on the importance of "Ability to make tough questions quickly" (TM: 0.633 REI, MM: 0.667 REI, FM: 0.600 REI)—highlighting this as the first priority (Rank 1).

Table 4. TDfS capabilities and REI rankings.

Technology Diffusion for Sustainability Capabilities/Factors	TOTAL			
	MS	**SD**	**REI**	**Rank**
Ability to make tough decisions quickly	3.167	0.874	0.633	1
Ability to change work habits as a response to changes in the demands	3.500	0.861	0.700	2
Ability to analyse the potential risks of change on organisational resources	3.533	0.819	0.707	3
Ability to quickly reorganise the resources in sudden change	3.567	0.858	0.713	4
Ability to develop trust to enable information sharing	3.633	0.890	0.727	5
Ability to be aware of emerging technologies, trends, and changes in the industry	3.800	0.887	0.760	6.5
Ability to manage knowledge efficiently	3.800	0.887	0.760	6.5
Development of a collaborative culture	3.833	0.747	0.767	8
Ability to assess recovery needs in sudden/unpredicted change	3.867	0.937	0.773	9
Ability to be aware of organisation's external connectivity	3.867	1.008	0.773	10
Modularity of IT infrastructure	3.900	0.885	0.780	11
Ability to be aware of level of organisation's resources	3.900	0.960	0.780	12
Ability to learn new procedures quickly	3.933	0.868	0.787	13
Ability to define a clear strategic vision for organisation	3.933	0.907	0.787	14
Development of an innovative culture	3.933	1.015	0.787	15
Staff's ability to work in different positions and responsibilities	3.967	1.098	0.793	16
Ability to reengineer the processes	4.033	0.765	0.807	17
Ability to clarify changes in roles and responsibilities	4.100	0.803	0.820	18
Ability to develop an IT strategy aligned with business strategy	4.133	0.730	0.827	19
Ability to employ IT and innovation ready staff	4.133	0.860	0.827	20
Empower staff to take decisions	4.167	0.699	0.833	21
Compatibility of IT infrastructure	4.167	0.950	0.833	22
Ability to develop solutions to accommodate sudden change	4.233	0.568	0.847	23
Ability to provide service and technical support within the company	4.267	0.785	0.853	24
Ability to provide technical support from outside of the company	4.333	0.844	0.867	25
Ability to improve skills, knowledge, and approach to new technology	4.600	0.498	0.920	26

Notes: MS—Mean Score of the existence where (1) strongly disagree (2) disagree (3) neutral (4) agree and (5) strongly agree; SD–Standard Deviation; REI—Relative Existence Index; Rank—Priority need ranking.

Factors from the TM level perceived to require the highest level of attention included: Rank 2 "ability to change work habits as a response to changes in the demands" (0.733 REI) and Rank 3.5 (shared by "Ability to analyse the potential risks of change on organisational resources" and "Ability to quickly reorganise the resources in sudden change" (0.767 REI)). Conversely, factors perceived to have the least importance were: Rank 26 "Ability to improve skills, knowledge, and approach to new technology" (1.000 REI) and Rank 24 (shared by "Ability to provide technical support from outside of the company", "Ability to provide service and technical support within the company", and "Development of an innovative culture" (0.933 REI)).

Table 5. TDfS capabilities and REI rankings (all management levels).

Technology Diffusion for Sustainability Capabilities/Factors	TM		MM		FM		TOTAL	
	REI	Rank	REI	Rank	REI	Rank	REI	Rank
Ability to make tough decisions quickly	0.633	1	0.667	1	0.6	1	0.633	1
Ability to change work habits as a response to changes in the demands	0.733	2	0.7	2	0.683	6	0.7	2
Ability to analyse the potential risks of change on organisational resources	0.767	3.5	0.75	7	0.633	2	0.707	3
Ability to quickly reorganise the resources in sudden change	0.767	3.5	0.75	5.5	0.65	3	0.713	4
Ability to develop trust to enable information sharing	0.833	10.5	0.733	4	0.667	4.5	0.727	5
Ability to be aware of emerging technologies, trends, and changes in the industry	0.867	16	0.8	13	0.667	4.5	0.76	6.5
Ability to manage knowledge efficiently	0.833	10.5	0.75	5.5	0.733	13	0.76	6.5
Development of a collaborative culture	0.8	5	0.8	12	0.717	9	0.767	8
Ability to assess recovery needs in sudden/unpredicted change	0.833	7.5	0.833	17	0.683	8	0.773	9
Ability to be aware of organisation's external connectivity	0.8	6	0.817	15.5	0.717	10	0.773	10
Modularity of IT infrastructure	0.867	16	0.717	3	0.8	19.5	0.78	11
Ability to be aware of level of organisation's resources	0.9	21	0.783	9	0.717	11	0.78	12
Ability to learn new procedures quickly	0.867	16	0.783	9	0.75	15	0.787	13
Ability to define a clear strategic vision for organisation	0.867	19	0.783	11	0.75	14	0.787	14
Development of an innovative culture	0.933	24	0.817	15.5	0.683	7	0.787	15
Staff's ability to work in different positions and responsibilities	0.833	13	0.817	14	0.75	16	0.793	16
Ability to reengineer the processes	0.867	16	0.85	22	0.733	12	0.807	17
Ability to clarify changes in roles and responsibilities	0.833	7.5	0.833	19	0.8	21	0.82	18
Ability to develop an IT strategy aligned with business strategy	0.9	21	0.85	23	0.767	17	0.827	19
Ability to employ IT and innovation ready staff	0.833	10.5	0.833	19	0.817	22.5	0.827	20
Empower staff to take decisions	0.833	10.5	0.867	24	0.8	19.5	0.833	21
Compatibility of IT infrastructure	0.9	21	0.783	9	0.85	25	0.833	22
Ability to develop solutions to accommodate sudden change	0.867	16	0.833	19	0.85	24	0.847	23
Ability to provide service and technical support within the company	0.933	24	0.85	21	0.817	22.5	0.853	24
Ability to provide technical support from outside of the company	0.933	24	0.933	26	0.767	18	0.867	25
Ability to improve skills, knowledge, and approach to new technology	1	26	0.9	25	0.9	26	0.92	26

Notes: TM—Top Management, MM—Middle Management, FM—First Line Management; REI—Relative Existence Index.

From a MM perspective, Table 5 highlights that MM respondents shared a similar view with TM respondents, identifying the "ability to change work habits as a response to changes in the demands" (0.700 REI) as the second most important factor (Rank 2), while "modularity of IT infrastructure" (0.717 REI) was placed in Rank 3. Conversely, the factors perceived by MM level participants as least important were: Rank 26 "Ability to provide technical support from outside of the company" (0.933 REI); Rank 25 "Ability to improve skills, knowledge, and approach to new technology" (0.900 REI); and Rank 24 "Empower staff to make their decisions" (0.867 REI).

From an FM perspective, the "ability to make tough questions quickly" was regarded as the area that required the highest priority (which concurred with both TM and MM findings). Other FM priorities perceived as the most important were: Rank 2 "Ability to analyse the potential risks of change on organisational resources" (0.633 REI) and Rank3 "Ability to quickly reorganise the resources in sudden change" (0.650 REI). Conversely, the areas perceived to have the lowest impact on technology diffusion capability were: Rank 26 "Ability to improve skills, knowledge, and approach to new technology" (0.900 REI), Rank 25 "Compatibility of IT infrastructure" (0.850 REI) and Rank 24 "Ability to develop solutions to accommodate sudden change" (0.850 REI).

4.3. Differing Perspectives across the Three Management Levels

One of the main reasons behind capturing the views and opinions from different levels of management was not just to secure a representative and balanced view. It was also in part to try and understand the level of thinking from three levels of expertise; where at the polar opposites FM would invariably be employees working and using new technology for operational delivery reasons; whereas, TM would predominantly be procuring technology for employees (such as FM and operatives) across the wider business. Given this, it was important to appreciate whether operational and strategic thinking coalesced, especially given the diverse perspectives of these three management levels. Given the need to identify the nature of these diverse perspectives across the three main strata groups, the following narrative presents: (i) areas of commonality of thinking, and (ii) views that differ significantly.

Prior to presenting a detailed introspective reflection on case study findings, it is important to note that there was a general consensus of thinking across all three management levels for most of the questions presented. Thus, polar extremes were not directly evidenced. This may in part be coincidental, or in fact, a by-product of the questionnaire construct or interpretation thereof. Notwithstanding this, the findings themselves present a rich opportunity to explore the subtle nuances and differences in thinking. For example, the "Ability to improve skills, knowledge, and approach to new technology" was perceived as being one of the most powerful capabilities of their company (TM: 26, MM: 25, FM: 26); where the "ability to make tough decisions quickly" (TM: 1, MM: 1, FM: 1) was regarded as a major weakness and barrier to this. Whilst some TM-level participants disagreed with this to some extent, they recognised this weakness, noting the need to counter this through a more detailed analysis. In addition, they also noted that decision-making processes were invariably influenced by a high level of bureaucracy, which in turn affected the speed of decisions, noting for example that " ... too much bureaucracy ... causes delays ... ". Participants highlighted the following four contributors to this problem:

- Existence of old decision-making mechanisms (cultural embeddedness);
- Ambiguous roles and responsibilities (power and authority);
- Communication problems (organisational structure);
- Staff avoidance in taking initiative (leadership).

There was a slight discrepancy in thinking between management levels on "Empowerment of staff to take decisions" (TM: 10.5, MM: 24, FM: 19.5). This highlights the concern of TM on the existence of this capability compared to the participants from the MM and FM levels. In this respect, TM participants did not concur, as they did not see this as empowerment. They underlined the fact that staff were unable to make decisions and implement them on their own, noting the need for staff to make their own decisions. Participants highlighted the following two contributors to this problem:

- Managers seemed unwilling to delegate their decision-making powers (power and authority);
- Vertical communication problems (organisational structure).

From an information-sharing perspective, the "Ability to develop trust to enable information sharing" (TM: 10.5, MM: 4, FM: 4.5) was another example of the areas where the perception of MM and FM levels showed a discrepancy (in comparison with the views of TM participants). However, the majority of the participants (especially TM), stressed the importance of trust and that, whilst some departments did not always want to share information due to protecting the position power balance, this was on the whole minimal—probably due to communication problems between the different construction sites and respective head offices.

Findings on issues covering the "Development of an innovative culture that supports the use of new technology" (TM: 24, MM: 15.5, FM: 7) also presented some differences of opinion across the three levels. Where, for example, TM believed in the importance of instilling an innovative culture within their respective organisations as this was seen to not only define their company as a pioneer but also to establish this as a vehicle for implementing innovative approaches. However, FM respondents challenged this in some respects, noting that whilst they believed in the importance of an innovative approach (as a guiding principle), this did not actually reflect what happened in practice. They also observed that company approaches to technology adoption were seen as a necessity—ergo, a pseudo prerequisite for winning a tender. MM respondents were somewhat ambivalent, balancing the need to be innovative, albeit counterbalanced with the need to use this technology in a meaningful (operational) way. Notwithstanding these differences, the importance of embedding technology into processes was clearly evident across all three levels. Anecdotally, it was interesting to note that resistance to new technologies seemed to be age-dependent, where younger staff (with a high familiarity with technology) were less concerned than those that did not have this familiarity/expertise. This in itself influenced the decisions organisations made, as it transpired that some organisations were not fully aware of the benefits of such novel technologies. Consequently, the choices and decisions made by TM were seen as a hybrid solution for (hopefully) improving the company's level of innovation. These findings are supported by the importance rankings, highlighting this perceived lack of awareness through the following rankings: TM (Rank 24); MM (Rank 15.5) and FL (Rank 7).

5. Discussion

5.1. Reflection on Core Challenges

The primary purpose of this research was to evaluate the perceptions of employees using offsite construction. In particular, how technology adoption and diffusion were harnessed to improve performance, especially against sustainability measures through TBL. In this respect, on the whole, sustainability perceptions were not specifically aligned to TBL—certainly not aligned to social, economic and environmental dimensions as proffered by Elkington, [4]. That being said, feedback from respondents noted the importance of sustainability, particularly in its practices and business processes. This (inter alia) required conjoined thinking, particularly on the social, economic and environmental dimensions, as collectively, this was seen to represent the company "image" and external "shop window" that this portrayed to the outside world. Thus, there was general consensus that the underpinning "glue" that brought these three dimensions together was the use of technology—ergo, adoption, absorption and diffusion). The three tiers of management noted that no formal integrative measure existed in either of the three case study companies and that some form of model or framework would be particularly useful to help them measure TBL, particularly through projects using offsite.

The following section presents an outline structure for a TDfS Technology Diffusion Model for Offsite Construction. This highlights the core integrative mechanisms linking the social, economic and environmental dimensions. In doing so, it also presents the need for organisations to deploy organisational dynamics to disentangle complexity [182,183], using this as a "super catalyst" for leveraging its value proposition [184].

5.2. Offsite Construction TBL Super Catalysts

Findings from this research highlighted that conjoined thinking was needed, not just across the three management levels, but also from a wider company perspective (for each of these three case study companies). It was evident that whilst the decision-making process on technology adoption in relation to TBL was barely functional, this was acknowledged as unsatisfactory and not really fit for purpose. This was in part due to the fact that respondents did not really understand the multi-layered and complex nature of the technology diffusion/adoption process, yet alone the "drivers" needed to support TBL. In this respect, the amalgamation of these technology diffusion drivers with "sustainability" factors resulted in the identification of Technology Diffusion for Sustainability (TDfS) capabilities. These capabilities were used to develop a TDfS Technology Diffusion Model for offsite construction.

Findings from three case study domains indicated the need for greater integrative decision-making. In particular, the need to share information and thought process on the "drivers" needed to support TBL. Findings from Tables 4 and 5 highlighted the areas of importance, particularly the technology diffusion capabilities, which support core business processes. Table 5 presents the TDfS capabilities and REI rankings across all management levels spanning the three case study companies sampled. From this, it can be seen that a new ranking is provided—representative of the REI. This new ranking is an aggregate across the three management levels. The rationale of this was to see how the ranking changed (cf. the REI placed by each of the three management levels), in order to "generalize" a collective view; that is, not to place a higher emphasis on one particular level in deference to another, ergo, favouring TM over MM or MM over FM. This aggregation (of ranking) served no other purpose other than to rank the factors in line with collective opinion; rather than analyse the rankings on an individual level. However, selective cross-correlation is reported where major differences in thinking occur. In summary, therefore, the total rankings from Table 5 were used to inform the constructs for TDfS Super Catalysts presented in Figure 4. For example, the highest three ranked TDfS capabilities (Table 5) highlighted the need to: (i) make decisions, (ii) change work habits, and (iii) analyse risk. These three organisational capabilities alone resonate with "Client Demand", "Uncertainty", "Market Forces" and "Legislation" (Figure 4). Where the TDfS Super Catalysts are used as vehicles for the organisation to apply measures (offsite metrics) to these in order to evaluate the impact on "People, Process, Technology and Strategy" within the organisation and concomitant product offering.

From Figure 4, it can be seen that organisational structures and systems need to be more purposefully aligned through core enablers. These enablers help align technology diffusion to sustainability criteria, thereby qualifying them as "catalysts" [185] or "super-catalysts" [184]. Hereafter, given the context of technology diffusion and sustainability, these are termed "TDfS Super Catalysts". Given the need for organisations to appreciate how TDfS Super Catalysts could be used to deliver offsite (as part of its wider business strategy), there was a need to present these catalysts in the form of a TDfS Technology Diffusion Model for offsite construction (Figure 4) to showcase the main interrelated components and dynamics which enable the technology diffusion capabilities of OSC organisations.

Figure 4 presents an outline structure for organisations wishing to understand the organisational dynamics, forces and constraints affecting TBL for offsite projects. In this respect, offsite is therefore placed at the heart of this relationship model as the governing vision and ethos of this influences all other activities. The secondary sphere includes four governance areas, notably: People, Process, Technology and Strategy [186]. These four spheres allow organisations to target influence points to support the product offering, in this case, the offsite solutions it has in the market. The next orbit around these four spheres is the TDfS Super Catalysts. These act as gateway measures by providing criteria for assessment. In simple terms, they act as filters to the final outer orbit, which includes six final spheres: "Client Demand"; "Uncertainty"; "Ethical Positioning"; "legislation"; "Market Forces"; and

"Societal Pressure". These six outer spheres are considered external drivers to the central core (offsite). In this respect, they are issues that the company has to directly address in order to deliver their market offering—ergo, their offsite product(s). In this respect, these six spheres are all interlinked by "TBL Sustainability Drivers", where each of these six spheres provides specific TBL criteria the company needs to consider/address as part of its product offering. These outer spheres were derived from the organisational technology adoption and diffusion drivers (Table 3), where the importance and need for these are reinforced in the literature [6,187,188]. The outer spheres act as governors, where they both shape and define the external market drivers. In this respect, the TDfS Super Catalysts provide the criteria for assessment and the People, Process, Technology and Strategy orbits act as focal points for this assessment. The corollary of this is that from an organisational perspective, organisations have a clear set of indicators and metrics to help them position their products and services. In doing so, they can not only provide tangible evidence to support TDfS criteria but also enhance their offsite offering with defined value-chain indicators.

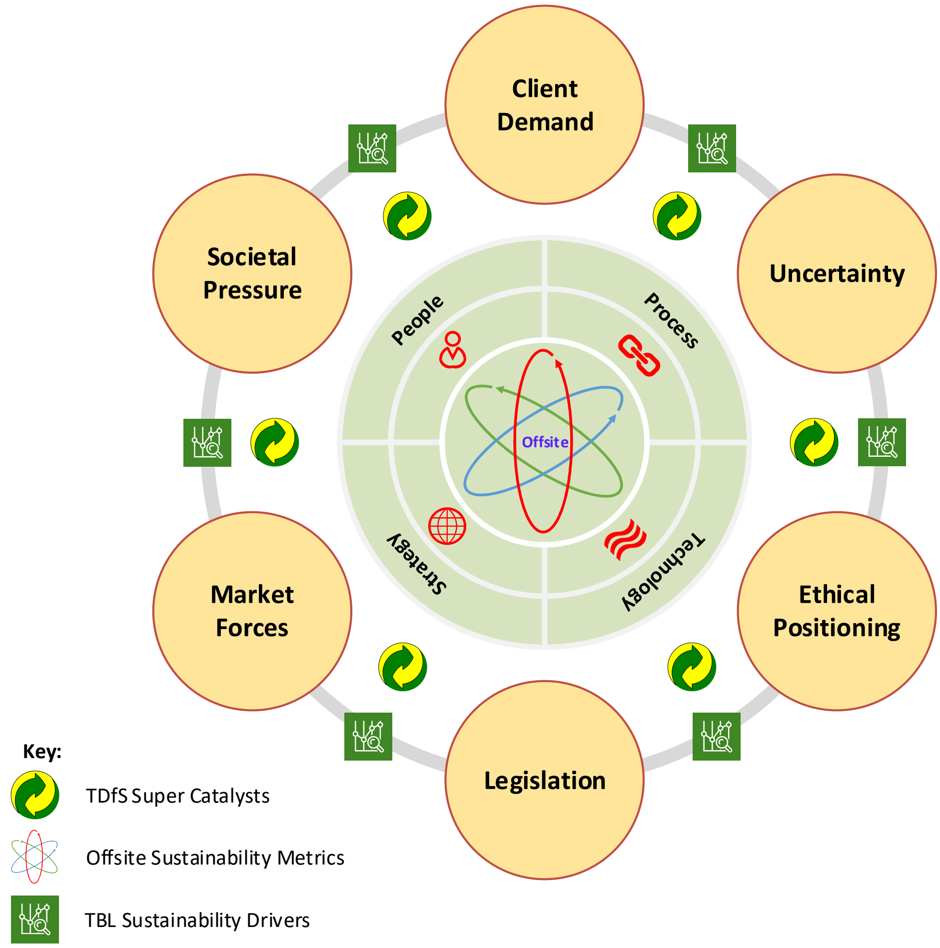

Figure 4. TDfS Technology Diffusion Sustainability model for offsite construction.

The model presented in Figure 4 presents the first step in defining these TDfS links. Organisations will naturally have to define the assessment criteria in accordance with their product offering, as a "one sized hat" solution would be unlikely to suit the myriad of offsite solutions on the market. That being said, it provides a landscape for further research. Reflecting back on the work presented in this paper, and in particular, how this relates to the development of the TDfS Technology Diffusion Sustainability Model for Offsite Construction, the following few observations are presented for discussion.

One of the issues emanating from this work concerned the "Ability to develop trust to enable information sharing". It was interesting to observe that across the three companies, and indeed across the three levels of management, certain challenges still existed with inter-organisational trust. Of particular note here is that this has been the subject of considerable debate over many years (cf. [189,190]). This by default can often affect a number of "awareness" issues [130,131], which ultimately impinge on the success or otherwise of new technology, change and organisational risk, particularly through the organisation's people, process, technology and strategy precepts. In this respect, it was acknowledged that organisational culture was certainly part of this issue, as respondents noted that this stifled effective decision-making, which in turn hindered progress and the level at which each company was able to compete. This aligns with similar findings where the type and level of organisational culture were seen to have a significant impact on the diffusion of novel technologies [136,137,141].

One of the major challenges organisations often face when considering the introduction of novel technologies, or indeed new systems, processes or products, is the impact this change will have on their existing systems and working practices. This includes the impact on employees, including skills, roles and responsibilities [181], and subsequent employee behaviour [191]. The findings from the work presented in this paper were no exception, as respondents continually reinforced the need to have well-developed "process management" capabilities to support the adoption and use of novel technologies. Moreover, the need to have conjoined thinking to support knowledge management and (ultimately) the decision-making capabilities of the organisation. This was seen to not only improve internal organisational awareness but also its external awareness and strategic direction (cf. "Client Demand"; "Uncertainty"; "Ethical Positioning"; "legislation"; "Market Forces"; and "Societal Pressure"), highlighted in Figure 4. This supports the thinking of Ferraris et al., [132] and consequently, the impact and alignment of strategy on the business [159,160].

Another important issue facing organisations is that of providing clear and effective leadership in order to minimise dissentients and improve collective thinking. Whilst findings from this work indicated some discrepancy in thinking (especially between Top Management and First Line Management), this was not considered counterproductive, as a common esprit de corps seemed to be present in all three companies. That being said, it is important to acknowledge that leadership can have a significant impact on the decision-making process; and ultimately, on the capabilities of employees within these organisations [149,150]. Moreover, respondents from this study also indicated that strong leadership helped foster trust within the organisation [165,166], and that power delegation was partly contingent on this. In addition, it is also important to reinforce the need to manage and balance power within organisations [163] as this can help reinforce transitional arrangements in times of change.

When organisations consider change, this can often manifest through several forms, typically as a consequence of planned or reactive change. This includes everything from remedial change (to address problems or issues) to transformational change (to realign the mission to meet criteria). Either way, change naturally invites many problems, from vertical and horizontal communication [167] to managing information and knowledge, leadership and the subsequent impact on business structures and processes [192,193]. The "golden thread" linking these things together is communication. Findings from this research highlighted a number of communication problems, where "messages" were unclear or misunderstood, not actioned or "lost in translation". This became particularly challenging, especially when this involved external communication with external stakeholders—the corollary of which was seen to stifle adoption [169]. This clearly resonates with the findings and thinking of Peansupap and Walker [23] regarding the need to purposefully support innovation diffusion, change management and knowledge sharing/learning.

Finally, reflecting back on the TDfS Technology Diffusion Sustainability Model for offsite construction (Figure 4), results from this work provide an indication of the complexity of these forces. They can be considered multi-layered, contiguous and intertwined. In summary, adoption and diffusion processes in construction organisations can be especially challenging [111,194]. That being said, organisational capabilities can be aligned to deliver corporate sustainability benefits [62,195]. Whilst the TDfS Super Catalysts presented in this paper provide new insight into sustainability and offsite, perhaps it is now time to develop gateway measures and criteria for detailed assessment.

6. Conclusions

This research stemmed from the need to create a more formalised approach for evaluating the impact of sustainability measures on companies engaging in offsite construction. In this respect, extant literature has called for further work in a number of key areas, from lifecycle costing to waste, carbon/environmental assessment, etc. However, this paper posited that whilst some of these intervention strategies have started to provide fruitful results, much more work is needed. This proposition was explored through three case study organisations to evaluate the key decision processes through three managerial tiers. This evaluated a number of factors, including sustainability practices, business processes and offsite, through to technology adoption/diffusion and the subsequent impact on organisational behaviour. Findings from this work were used to develop a TDfS Technology Diffusion Sustainability Model for offsite construction. This model promotes TDfS Super Catalysts as a way in which organisations can more clearly align their offsite operations to meet sustainability criteria. In doing so, it also presents a clear case for "conjoined thinking" in order to encourage organisations to evidence their offsite sustainability credentials.

One of the main findings emanating from this work is the need to acknowledge the importance of improving sustainability, not just in the products and services but throughout the whole supply chain. This is simply not a case of "doing the right thing"; it is about making sure that organisations appreciate the wider impact of sustainability through all their business processes (and the respective decisions they make). Whilst this work used offsite as a business context, using three organisations' abilities to diffuse and use novel technologies as an exemplar, the TDfS Technology Diffusion Sustainability Model for offsite construction is only the first step in this process. Detailed metrics are now needed to "ground" this model using performance indicators. These are likely to encompass company-specific strengths, focussing on unique or novel capabilities that showcase its core sustainability-driven ethos. Finally, whilst this work uncovers new meaning and insight, particularly on organisational theory and dynamics; equally, it is also important to highlight that this work was predicated on three case study companies, across three managerial levels, using specific TDfS criteria for offsite. In this respect, from a generalisability and repeatability perspective, this model should therefore be viewed as being context-bound by these anchors.

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