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Development of a Digital Innovation Framework that is Renowned Globally

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Abstract

The evolvement of the digital era/Industry 4.0 forces us to think differently about our life, new product development, new manufacturing environment, new communication procedures and even new ways of managing innovation in today's digital era. Industry 4.0 shifts the manufacturing lines' dynamics and improves organisations' profit. Innovative management substantially changes the world's smart transformation perspective in the manufacturing and services industries. Very little research was found on the digital era implication on innovation management. Therefore, this paper aims to develop a digital innovation framework that considers almost the globe's involvement during the development and validation stages. This includes seven prestigious countries from the major parts of the world, namely; the UK, UAE, USA, Germany, Japan, China, and Canada.

The proposed innovation framework was developed based on the practitioner's contributions from these seven countries, considering the impact of digitalisation-push and the demand-pull as main criteria, with many sub-criteria associated with each main criterion. The framework is then validated through a comprehensive questionnaire administrated by the practitioners from each of the mentioned seven countries using the Analytical Hierarchy Process (AHP), which has the flexibility to combine quantitative and qualitative mixed-methods and is used to collect data and carry out a pairwise-comparison between main criteria and sub-criteria. Moreover, the proposed framework provides the innovation processes required to handle the demand-pull and consider the digitalisation push.

Keywords: Innovation, Digitalisation-Push, Demand-Pull, Industry 4.0

1. Introduction

Modern manufacturing is primarily characterised by increasing competition between each other. On the other side, the economy, manufacturers, firms, and organisations are experiencing continuous change due to artificial intelligence

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(AI) [1]. Organisation survival and prosperity in a globally increasingly competitive environment are intense in the international R&D. while Industry 4.0 is frequently related to adding value to the manufacturing process and services; therefore, digital transformation is realised by linking indstry4.0 technologies to smart and intelligent factories and organisations. That requires companies to use to this atmosphere by working on innovative techniques and designs to propose new products, services, and processes while controlling costs and lead time to be differentiated and thus make their improvement more durable and robust [2]. Some empirical studies emphasised that I4.0 technologies can generate significant benefits for manufacturers in improving flexibility, decreasing cost, developing productivity and quality, and cutting delivery time [3]. In this context, R&D has been widely confirmed that improving a firm's technological combination through innovation is crucial to boosting productivity and service levels [4]. Moreover, using technologies, strategies like designing real-time interactions, creating key performance indicators to measure digital marketing, production and encouraging innovation in the digital era are facilitated to adopt digital technologies [5]. Consequently, now industries and companies require a new digital innovation process for intelligent and digital product-service systems to fulfil user innovation needs, requiring a digital innovation framework for the adequate digital era. Hence, this research aims to develop a digital innovation framework to provide a dynamic, continuous stream of innovation management from the demand-pull and digitalisation-push perspectives.

1.1. Innovation Models Journey

Innovation has a crucial role in achieving a competitive advantage that ultimately leads to increased global economic competitiveness. Innovation management theory is commonly exemplified as a theory that matches one's prerequisites. Hence, over 70 years, seven generations of innovation process models have been presented and summarised, as shown in Fig.1.Industrialised countries must change their activities to survive in the long-term. The futures demand market is a significant innovation resource; strong competencies enable the organisation to match intelligent sources with demand; thus, external and internal innovation sources are essential [6]. Researchers stated that any innovation management framework should thus include a good combination of structure and flexibility to deploy all the elements of successful innovation [7].

2. Developing the Conceptual Dynamic Digital Innovation Framework

The previous section presented the different generations and a few explicit examples. It synthesises a perception that balances the digital innovation process's intelligent technologies and market dimensions, and the output is a management framework for the digital innovation era. The conceptual innovation framework will exhibit the industrial demand to exceed organisational innovation and substantially meet global competitiveness. The empirical innovation framework is divided into two main criteria 1) *Demand-Pull for future market shape*, 2) *Digitalization-Push*.

2.1. Demand-Pull

In contrast to prior innovation frameworks and attempts to observe innovation as an organisational phenomenon, the new framework will present unique aspects for future demand. Hence, the proposed framework in this study will seek to create performance indicators for innovation that can be adapted to each sector's characteristics and indicate a model timeline of future modifications that a given organisation must make to maintain a competitive advantage. According to Rothwell, empirical and practical studies of innovation in the last half of the 1960s emphasised innovation as a product of 'pull' or market-led influences in need or require [8]. Various studies have been published since the 1960s that emphasise the marketplace's role in innovation [9] and [10]. Innovation provides powerful leverage to enhance and improve company performance and enable a company to continue successfully in the marketplace. Demand-pull is one of the main criteria for innovation framework, containing seven sub-criteria, as shown in Fig 2.

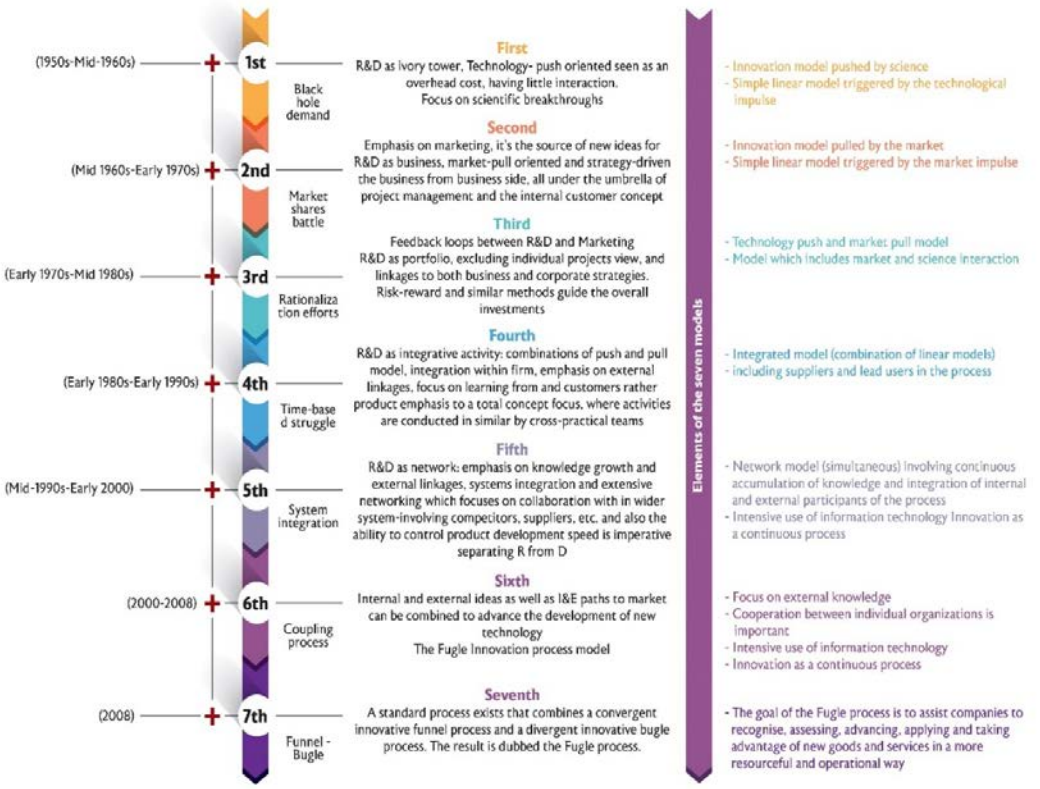

Figure1.The Journey of Seven Generations of innovation models [8,9,10,11,12,13, and 14]

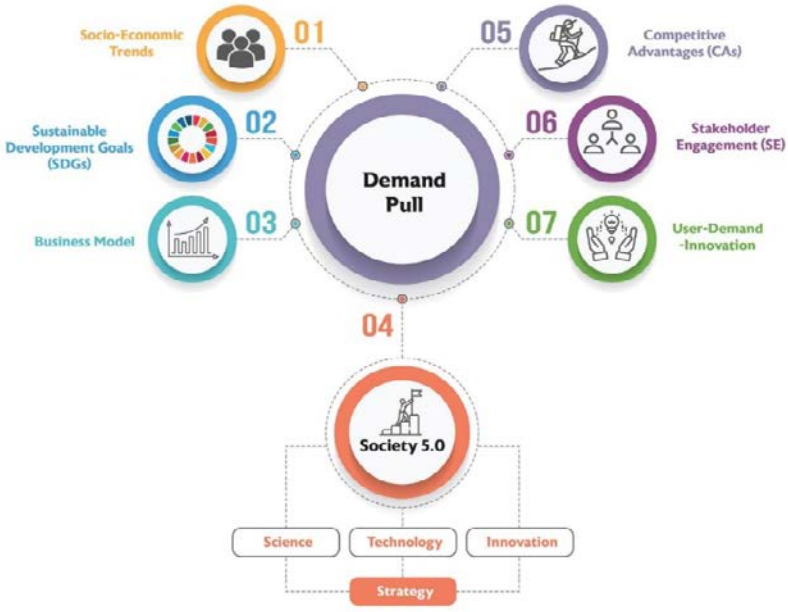

Fig 2: Demand-pull criteria

2.2. Digitalisation-Push

With the specular user interface of the ongoing digital revolution, the holy grail of the efficiency revolution gets yet another new finish; By digitalising, almost every aspect of production and consumption can increase organisational efficiency even more [11]. Digitalisation is the most phenomenon topic in the 21st century; digital technologies have significantly influenced talent management and human resource systems. Moreover, digital technologies are predicted to overshadow the industrial revolutions of the past century [12]. Additionally, digitalisation makes businesses act rapidly in a short time frame where there is a need to modify entire strategies and cultures; also, creating key performance indicators to measure digital marketing and personalising and encouraging innovation in digital marketing are facilitated by adopting digital technologies [13]. Digitalisation-push is the second main criterion and comprises seven sub-criteria. Industry4.0 was proposed as one of the most critical sub-criteria which effectively contribute to the digital transformation of an organisational with the goal of sustainable development, as illustrated in Fig 3.

Fig.3 Digitalisation-Push Criteria

3. Research Methodology

The main objective of the research presented in this article was to propose an innovation framework in the digital era. Thus, it offered a systematic literature review to analyse the relationship between the previously reported seven generations of the innovation models. Moreover, data collection was based on the pairwise comparison questionnaire distributed within the seven prestige countries (UK, UAE, USA, Germany, Japan, China, and Canada).The sample sizes for each country are shown in Table.1. The questionnaire was developed in two languages (English and Japanese) and divided into two main parts, as explained earlier. Demand-Pull is the first central part and sets the most critical management sub-criteria in the organisation. On the other hand, the second principal criterion, Digitalization-Push, is the second primary criterion linked to the most compulsory sub-criteria in the digital era, as shown in Figures (2&3).

Table 1. The Global Sample Sizes

Country	UK	UAE	USA	Germany	China	Japan	Canada	Total
Response numbers	50	60	50	50	50	55	50	365

3.1. Analytic Hierarchy Process (AHP)

Data has been used to develop and validate the innovation framework using the analytical hierarchy process (AHP) to establish the criteria weights in multi-criteria decision-making (MCDM). Thomas Saaty [14] invented the AHP system in 1980. It can ranks and categories easily and effectively [12]. It calculates the desirable weights associated with criterion map layers with the help of a performance matrix; all identified relevant criteria are compared against each other with preference factors. The consequences can be gathered using criterion maps comparable to weighted combination methods. As well as to compare the importance of (n) criteria, a reciprocity performance relation has been generated automatically using AHP based on the pairwise comparisons using Saaty's (1-9) scale (Table 2&3) [13]. Fig. 4 shows a screenshot of the proposed framework, including the Demand-Push and Digitalisation-Push as the main criteria and then the associated sub-criteria for each based on the data collected from the seven countries involved in this study.

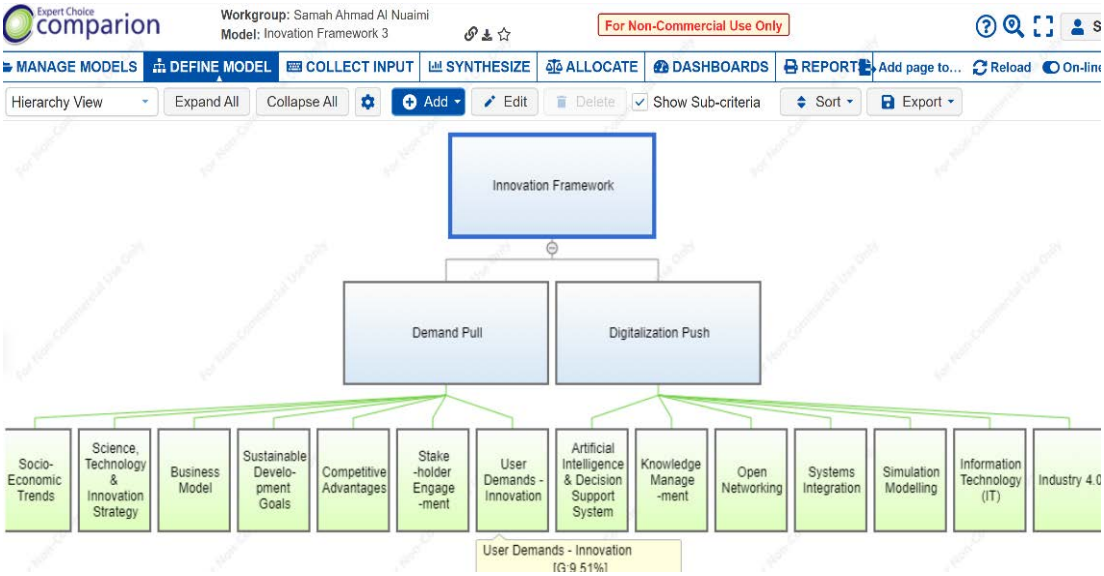

Table 2. Pairwise Compare Matrix of Selection Criteria.

	Criterion *i*	Criterion *j*	Criterion *k*
Criterion *i*	1	Criterion *ij*	Criterion *ik*
Criterion *j*	Criterion *ji*	1	Criterion *jk*
Criterion *k*	Criterion *ki*	Criterion *kj*	1

Table 3. Saaty's 1-9 Scale for AHP Performance

Intensity of importance	1	3	5	7	9	2 , 4 , 6 , 8
Definition	Equal	Moderate	Strong	Very Strong	Absolute importance	Intermediate values

Fig.4 Developing the Proposed Innovation Framework

4. Results and discussion

The most vital aspect of research is the analysis of data. Data analysis encompasses examining, categorising, charting, and recombining the collected data. This section sorts the data analysis of the global input.

4.1. The relative importance of the criteria and sub-criteria of the proposed innovation framework

Fig.5 represents the relative importance of the criteria and sub-criteria obtained at the global level, including the seven countries involved in this research. Global exploratory questionnaire result shows, predictably, that the overwhelming majority (76.92%) of *Digitalisation-Push* is the most effective area of innovation criteria, followed by 23.08% *Demand-Pull*; on the other hand, *Industry4.0* is noticeable as the significant sub-criteria with 20.08%.

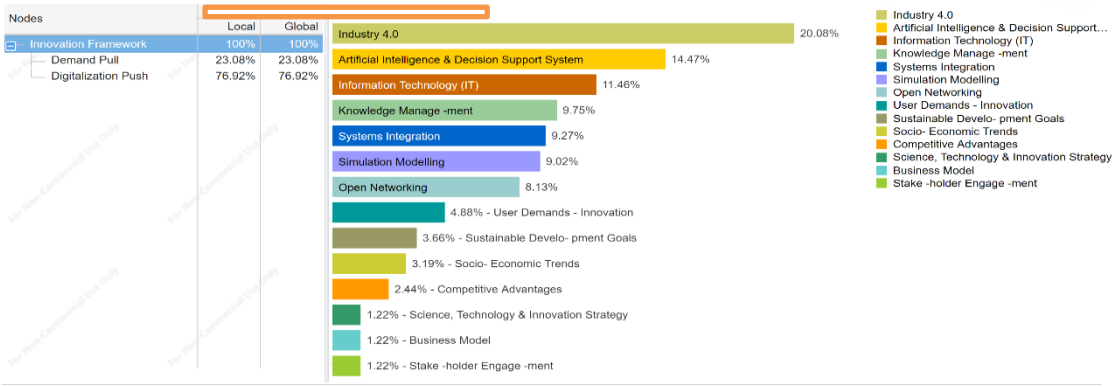

Fig.5 The relative importance of the (Main/Sub-Criteria) at Globl level

Fig.6 *displays* the UK results; it reveals that there has been a marked increase in the percentage of *Demand-Pull of* 56.00%, as opposed to *Digitalisation-Push of* 44.00%. Correspondingly, the most imperative factor that has reached a peak regarding the sub-criteria is *User Demands-Innovation*, which deliberated 10.76%.

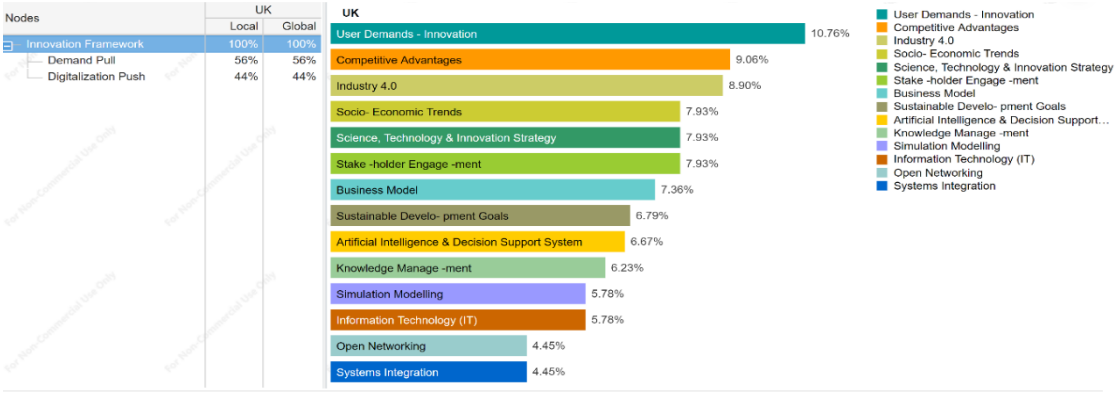

Fig.6 The relative importance of the (Main/Sub-Criteria) for the UK

4.2. Sensitivity Analysis

Sensitivity Analysis (SA) definition varies according to its application in practice. The consensus concludes that SA is a science that studies how the uncertainty in the output can be apportioned to the various uncertainties in the

input [15]. In addition,, the SA can also help reduce the uncertainties in the model output to a small threshold by adjusting the values of the input parameters. This ability is known as model input prioritisation [16].

Implementing sensitivity analysis is crucial to ensure the reliability of the final decision through the investigation of different scenarios and observation of the impact of changing the priority of the criteria on the alternative ranking system. Therefore, this study will examine various scenarios to observe changing the weighted criteria on the alternative ranking. For example, Fig 7 shows the sensitivity analysis when the weight for both Digitalisationp-Push (DI_P) and Demand-Pull (DE_P) was 50% each.

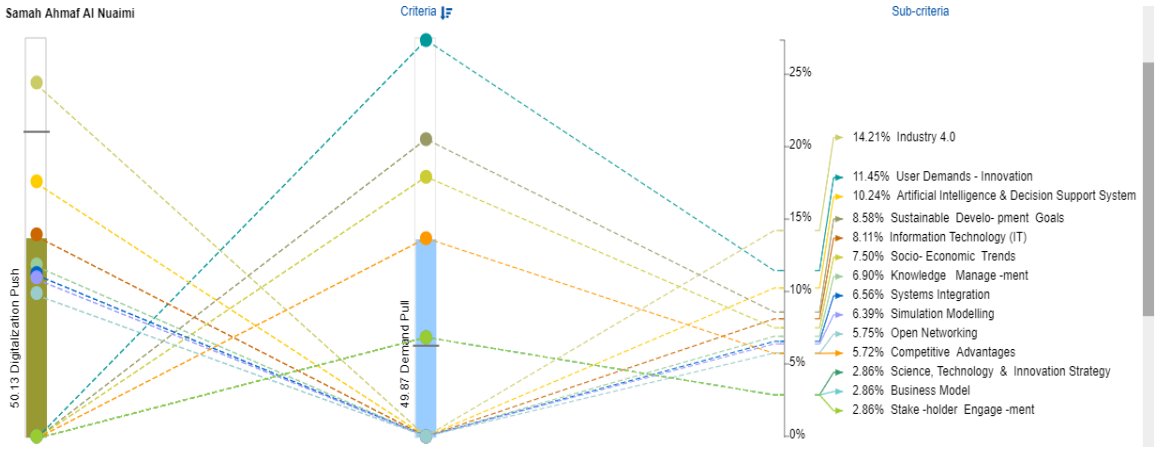

Fig.7. Sample of Globally Performance Sensitivity Analysis [Digitalisation-Push (DI-P)(50%) - Demand-Pull (DE-P)(50%)]

The detailed sub-criteria obtained for this scenario are presented in Table 4, column 2 and the corresponding percentage of priority for each sub-criteria in column 3. Whereas the rest of the table represents the different scenarios considered during the sensitivity analysis, namely: 40/60, 60/40, 70/30, 30/70. As can be seen, Industry 4.0 (I4.0) and User Demand Innovation (UDI) are dominant important criteria. Similarly, Table 5 provides the results for the UK data, which has almost the same conclusion. However, due to space limitations, the sensitivity analysis for the other countries will be presented at the conference.

5. Conclusion

This research developed a new digital innovation framework which is renowned globally from seven major countries, namely: UK, UAE, USA, Germany, Japan, China, and Canada. Validation of the proposed new generation innovation framework was based on feedback from the seven global countries, which was crucial for the research methodology. Digitalisation-Push and Demand-Pull were the primary criteria for accomplishing the goal of the future innovation framework; the diverse, Digitalisation-Push and Demand-Pull as main criteria were carefully chosen after conducting a thorough literature review and the opinion of the participants from the above seven countries. Thus, the priorities of these criteria were carefully calculated based on the data collected globally, which implies that the final proposed framework fits its purpose. There was substantial evidence from the seven countries that participated in the research that Digitalisation-Push and Demand-Pull play equally significant roles in the successful innovation identification and delivery. From the Digitalisation-Push sub-criteria views, Industry 4.0 are the topmost requirement in the seven countries; moreover, Artificial Intelligence and Decision Support Systems, Information Technology, and

Simulation Modeling were the most influential in assisting innovation. On the other hand, in the Demand-Pull sub-criteria, User-demand Innovation fared the highest among participants in terms of how important this was to trigger innovation. It was expected that international organisations' main drivers behind innovation needs are to be an industry leader and gain market share.

Table 4. Performance Sensitivity Analysis of Global (Seven Countries) Scenarios

%	DI-P(50%) DE-P(50%)	%	DI-P(40%) DE-P(60%)	%	DI-P(60%) DE-P(40%)	%	DI-P(70%) DE-P(30%)	%	DI-P(30%) DE-P(70%)
14.21%	I4.0	14.23%	UDI	16.48%	I4.0	18.64%	I4.0	17.23%	UDI
11.45%	UDI	11.72%	I4.0	11.88%	AI&DSS	13.43%	AI&DSS	12.92%	SDG
10.24%	AI&DSS	10.68%	SDG	9.41%	IT	10.64%	IT	11.29%	SET
8.58%	SDG	9.32%	SET	8.90%	UDI	9.06%	KM	9.04%	I4.0
8.11%	IT	8.45%	AI&DSS	8.01%	KM	8.60%	SI	8.62%	CA
7.50%	SET	7.12%	CA	7.61%	SI	8.38%	SM	6.52%	AI&DSS
6.90%	KM	6.69%	IT	7.41%	SM	7.55%	ON	5.16%	IT
6.59%	SI	5.69%	KM	6.67%	SDG	6.49%	UDI	4.39%	KM
6.39%	SM	5.41%	SI	6.67%	ON	4.86%	SDG	4.31%	ST&IS
5.75%	ON	5.27%	SM	5.83%	SET	4.25%	SET	4.31%	BM
5.72%	CA	4.74%	ON	4.45%	CA	3.24%	CA	4.31%	SHE
2.86%	ST&IS	3.56%	ST&IS	2.22%	ST&IS	1.62%	ST&IS	4.17%	SI
2.86%	BM	3.56%	BM	2.22%	BM	1.62%	BM	4.06%	SM
2.86%	SHE	3.56%	SHE	2.22%	SHE	1.62%	SHE	3.66%	ON

Where:

UDI – User Demand Innovations, **AI&DSS** – Artificial Intelligence and Decision Support System, **SDG** – Sustainable Development Goals, **IT** – Information Technology, **SET** – Socio-Economic Trends, **SI** - System Integration, **KM** – Knowledge Management, **CA** – Competitive Advantages, **I4.0** – Industry 4.0, **SM** – Simulation Modelling, **ON** – Open Networking, **ST&IS** – Science Technology and Innovation Strategy, **BM** – Business Model, **SHE** – Stake Holder Engagement

Table 5. Performance Sensitivity of The UK Scenarios

%	DI-P(50%) DE-P(50%)	%	DI-P(40%) DE-P(60%)	%	DI-P(60%) DE-P(40%)	%	DI-P(70%) DE-P(30%)	%	DI-P(30%) DE-P(70%)
10.19%	I4.0	11.49%	UDI	12.27%	I4.0	14.46%	I4.0	13.35%	UDI
9.61%	UDI	9.68%	CA	9.20%	AI&DSS	10.84%	AI&DSS	11.24%	CA
8.09%	CA	8.47%	SET	8.59%	KM	10.12%	KM	9.83%	SET
7.64%	AI&DSS	8.47%	ST&IS	7.98%	SM	9.40%	SM	9.83%	ST&IS
7.13%	KM	8.47%	SHE	7.98%	IT	9.40%	IT	9.83%	SHE
7.08%	SET	8.06%	I4.0	7.77%	UDI	7.23%	ON	9.13%	BM
7.08%	ST&IS	7.86%	BM	6.54%	CA	7.23%	SI	8.43%	SDG
7.08%	SHE	7.26%	SDG	6.13%	ON	5.84%	UDI	5.97%	I4.0
6.62%	SM	6.05%	AI&DSS	6.13%	SI	4.91%	CA	4.48%	AI&DSS
6.62%	IT	5.65%	KM	5.73%	SET	4.30%	SET	4.18%	KM
6.58%	BM	5.24%	SM	5.73%	ST&IS	4.30%	ST&IS	3.88%	SM
6.07%	SDG	5.24%	IT	5.73%	SHE	4.30%	SHE	3.88%	IT
5.10%	ON	4.03%	ON	5.32%	BM	3.99%	BM	2.98%	ON
5.10%	SI	4.03%	SI	4.91%	SDG	3.69%	SDG	2.98%	SI

Where:

UDI – User Demand Innovations, **AI&DSS** – Artificial Intelligence and Decision Support System, **SDG** – Sustainable Development Goals, **IT** – Information Technology, **SET** – Socio-Economic Trends, **SI** - System Integration, **KM** – Knowledge Management, **CA** – Competitive Advantages, **I4.0** – Industry 4.0, **SM** – Simulation Modelling, **ON** – Open Networking, **ST&IS** – Science Technology and Innovation Strategy, **BM** – Business Model, **SHE** – Stake Holder Engagement

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