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Industry 5.0 Transition for an Advanced Service Provision

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Abstract

The current service provision for high-value manufactured equipment is transitioning from a purely product-focused business model to a service-focused one, known as servitization. Businesses aim to continuously improve their service offerings to sustain customer satisfaction in order to maintain their competitive edge within the industry. On the other hand, Industry 5.0 is characterized by bringing industries' focus towards collaboration for sustainable value co-creation rather than producing goods and services for profit. This research investigates the possible enablers to design and deploy a highly effective advanced service provision. Advanced service provision refers to providing service solutions that fulfil the desirable availability, capability, and reliability in product-service contracts. The research outcomes are presented in the form of a transition framework and a set of recommendations towards the desired future state, with phased timings for implementing the key enablers with a potential 2035 vision to support the Industry 5.0 transition. The validity of the framework was tested by collecting experts' opinion who currently work within servitization contracts. The outcome of this study can be generalized for industries in high-value manufacturing.

Keywords: Industry 5.0; Industry 4.0; Servitization; Maintenance; Reliability; High-value manufacturing

1. Introduction

The fifth industrial revolution, known as Industry 5.0 (I-5.0), goes beyond economic provisions and profitability for industries. It embraces social provisions to provide prosperity and wellbeing while targeting economic growth. I-5.0 highlights the importance of sustainable development goals for industries. I-5.0 obligates industries to play a more important role in providing solutions for preserving resources, preventing climate change, and improving social prosperity. This prospect will make industries more resilient against social and environmental disruptions, e.g. Covid-19, global warming, and rise of sea-level. I-5.0 has four main elements: (i) adopting a human-centric approach for digital technologies including artificial intelligence, (ii) up-skilling and re-skilling human resources, particularly digital skills, (iii) modern, resource-efficient and sustainable industries and transition to a circular economy, (iv) a globally competitive and world-leading industry, speeding up investment in research and innovation [1]. In a nutshell, I-5.0 is about promoting the ethics of technologies and making industries sustainable.

Industry 4.0 (I-4.0) technologies brought vast excitement and advancement for the high-value industry, businesses, and technology developers. General Electric uses Augmented Reality (AR) technologies to train and transfer expert knowledge and digitalise instructions through production. BJC healthcare spent millions of dollars to adopt IoT and RFID technologies across the inventory and supply chain. Leading aerospace, energy and transport industries are deploying robotics, additive manufacturing and Digital Twin (DT) across the globe. Nevertheless, the fourth industrial revolution triggered fear of losing job envisaging the replacement of workers with robots, and it caused workers to feel unsafe, and incompetent when compared to robots. The current understanding of the I-5.0 vision regarding technological innovation is not too dissimilar to I-4.0, still it entails a touch of ethical and planetary value promotion. Some of the I-4.0 technologies such as Cyber-Physical Systems (CPS), Internet of Things (IoT) and blockchain are susceptible to systemic risk and challenges such as cyber-attacks. I-5.0 technologies aim to revolt the social values and human-centric visions to resolve these issues.

The current market for high-value products is undergoing a transition from a pure product-focused business model to providing a service-based business model known as servitization. A definition of servitization is provided by [2] as "the increased offering of fuller market packages or 'bundles' of customer-focused combinations of goods, services, support, self-service and knowledge to add value to core product offerings". This is analogous to the movement of the manufacturing industry from providing value from selling a product towards defining the value from selling a service and through-life support to the customers. High-value manufacturers are required to determine their system maintenance and service provisions to deliver a

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highly effective future-state servitization offering for the upcoming I-5.0 requirements.

In this study, the current state of I-4.0 and digital servitization are specified using the TES framework for an aerospace sector case study in the UK [3]. In addition, a systematic review is conducted to identify the key technological enablers of I-5.0 for an advanced service provision. Finally, a recommended phased roadmap was created, which outlines the key enablers that high-value service provision systems should implement to achieve I-4.0 and I-5.0.

2. Literature review

In 2016, Romero Díaz et al. [4] introduced the concept of 'Operator 4.0' to promote the human-centric perspective of I-4.0. Different roles are defined for an operator within a human-automation cooperation work system. Their study concluded that I-4.0 and socially sustainable manufacturing would be achievable in its full potential when Operator 4.0 (human-robot collaboration) is at the centre of industrial technologies. Ariansyah et al. [5] highlighted the role of the human in the future industrial revolution with the focus on human integration in industrial DT. Their research suggested that in a hybrid human-DT workspace, collecting and integrating the relevant human data can enhance the adaptiveness of the DT system to the human operating environment.

Martynov et al. [6] proposed the potential emerging approaches and technologies that assist industries transitioning from I-4.0 to 5.0. These technologies are IoT, multi-agent systems (or System of Systems), ontology and knowledge bases, complex adaptive systems, artificial emergent intelligence, and evergetics. Chen et al. [7] explored the concept of human-cyber physical system (HCPS) in the context of I-5.0 technologies. In a recent study, Alvarez-Aros and Bernal-Torres [8] conducted a systematic review on technological competitiveness and the emerging technologies of I-4.0 and 5.0. Their research shows that the top three technological elements for developing economies are smart manufacturing, IoT, and organisational structure for sustainability. Whereas, for developed economies, the element of 'big data analytics' is next to the former two elements.

Servitization offers a set of integrated product-service provision business models known as Product-Service System (PSS) [9]. A successful PSS aims to control the entire lifecycle of a product, from acquisition to disposal. Such business models reduce the level of risk associated with a service contract since the manufacturer maintains the control of the service data. Servitization requires a high level of collaboration with the customer over the in-service phase of the product lifecycle. In this phase, product reliability and service improvements are made through in-service data analysis [10]. Servitization can be observed within large engineering companies offering high-value goods to their customers. An example of this is Rolls-Royce servitization strategies to move from selling engines as a unit, to, instead, selling engine hours as a service through their 'Power by the Hour™' contract [11].

Gökalp et al. [12] proposed a framework that shows a step-by-step industrial capability and technical readiness levels in the context of I-4.0. Businesses are required integrated engineering and through-life product support to be at the final capability readiness level of their framework. Complete synchronisation between a product and its services should be achieved. This integration enables businesses through low-effort knowledge sharing. Kamp et al. [13] identified their main capability requirement for industries seeking digital servitization, which are the capability to 'determine, capture and transmit relevant data', 'exploit data and convert data into actionable knowledge', and 'build trust between manufacturer and customer in order to come to effective data exchange'.

Bibby and Dehe [14] developed an assessment model to measure the level of Industry 4.0 implementation based on three dimensions of 'Factory of the Future', 'People and Culture', and 'Strategy'. The key technologies are defined as 3D-printing, additive manufacturing (AM), cloud, manufacturing execution system (MES), IoT and CPS, big data, sensors, e-value chains, and autonomous robots.

Weking et al. [15] proposed a framework and a taxonomy to characterise I-4.0 business models. They identified several patterns for PSS business models by applying the taxonomy to several case studies. Their research concluded that a sustainable business model is needed for a successful digital transformation through I-4.0. In a recent study, Pirola et al. [16] conducted a semi-systematic literature review on the combination of digital technologies with PSS. They identified five research areas within the future servitization: PSS design, digital servitization, PSS decision tools, lifecycle knowledge management, and sustainable business models.

Existing literature highlights the importance of I-4.0 for enhancing the integration of different parts of a service provision [17]–[20]. The existing I-4.0 maturity models and frameworks can be used to determine the current state and future requirements for businesses. This study contributes to research by specifying the current state of I-4.0 implementation in servitization, utilising a case study in the aerospace industry in the UK. Moreover, I-5.0 technological enablers to design the future advanced service provision are identified.

3. Methodology

This study investigates the current state of I-4.0 implementation and digital servitization in high-value manufacturing.

Step 1 - Problem statement (Section 1): this paper aims to identify the I-5.0 technological enablers for future advanced service provisions.

Step 2 – Data collection (Section 2): this study conducts a systematic review to identify and select the existing literature in 'Industry 5.0' and 'Industry 4.0 in servitization'. In addition, a primary data collection is completed by sending a survey to 60 experts within a high-value manufacturing sector in the UK. Due to Covid-19 restrictions, 7 responses were collected in the end. The survey includes 16 questions to assess experts' knowledge on (1) the current state of digital maintenance, (2) the contractual and cultural mechanisms that either support or hinder the effectiveness of their operations, and (3) the key operational changes that improve the effectiveness of their current or future programme.

To review the relevant literature on 'Industry 5.0', three research repositories of Scopus, Web of Science (WoS) and Google Scholar were searched with no lower time-limit, and up to June 2021. Since the concept of Industry 5.0 is new, in Scopus and WoS, the only inclusion criteria using the 'Industry 5.0' search keyword, was the studies disseminated in 'English'. The following keyword string was therefore used to define the initial database of documents: TITLE-ABS-KEY ("Industry 5.0"). Following PRISMA 2009 framework, in the 'identification' stage, the search revealed 70 and 41 research works in Scopus and WoS, respectively. Subsequently, in the 'screening' stage, after reviewing the title and abstract of the documents, the articles in the context of education, medical, and biology were eliminated. Moreover, duplicate articles obtained from both search repositories were excluded, and only one copy was retained. At this stage, a further 87 articles were excluded. At the final stage, the full-text articles were fully reviewed and assessed for their eligibility. To search for literature about Industry 5.0 for servitization, the keywords 'Industry 5.0' and 'servitization' or 'product-service system' or 'PSS' where considered. No article was found in Scopus and WoS. However, Google Scholar (GS) identified 24 studies in total. Articles in 'English' with their full-text available were included. After reviewing the titles, 18 GS links were found irrelevant. The title and abstract of the remaining 6 documents were reviewed. No article has been selected at this stage due to the lack of originality, and relevance to Industry 5.0 and servitization. This left a total of 18 articles for review.

Step 3 – Data analysis and discussion (Section 4): the TES framework for through-life service provision [3] is used to map the As-Is advanced service provision state following the literature review and the data collected from the experts' knowledge. Afterwards, A recommended phased roadmap was created, outlining the stages that high-value service provision systems could implement to achieve I- 5.0 capability successfully. Finally, the As-Is model is tested by the experts who currently work with servitization contracts.

Step 4 – Conclusion (Section 5): Time-phased recommendations are designed for high-value advanced service provision within I-5.0 vision. In conclusion, the research highlights, limitations, and opportunities for further work are outlined.

4. Results and discussion

The service contracts developed in high-value industries are mainly defined around performance, capability and the reliability levels that the customer receives from the products. Equipment availability is a key measure of the PSS effectiveness and, in turn, the ultimate mission readiness. From a systems analysis point of view, the relationship between performance, capability and availability can be defined by three measurements of 'operational readiness', 'dependability and reliability', 'mission success and capability', and 'technical readiness'. Operational readiness can be evaluated based on equipment availability, reliability, maintainability, and supportability. The key performance indicators (KPI) of advanced service provision are availability, capability, and reliability in providing service solutions. Together with the operating and operational support cost, these KPIs define the mission success. Technical readiness are measured by the level of digitalisation and implementation of I-4.0 within products, services, value chains, product-service offerings, business models and manufacturer-customer communication. I-4.0 is still in motion and is expected to have a significant impact on supply chains and the current business models. It is expected that I-4.0 will fully support I-5.0 by promoting ethics and sustainable development goals.

This section presents the As-Is state of advanced service provisions based on the survey responses and the literature review outcome. Moreover, the future roadmap towards I-5.0 is proposed based on the relevant literature in I-5.0 and digital servitization, as detailed earlier in Section 2. The survey focused on advanced service provision KPIs and key enablers in terms of key dependencies, changes, lessons learnt, and culture within businesses. The survey output is summarised in Table 2.

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Table 2. Summary of key survey findings on As-Is state of advanced service provision

KPIs	Survey output
Availability	The current maintenance contracting supports availability; availability target is achieved by efficiently utilising maintenance to reflect the customers' requirements.
Capability	The current maintenance contracting supports capability; capability may include meeting the customers' requirement in terms of technical training to enhance competencies.
Reliability	The current maintenance contracting supports reliability; short-term reliability contract should be the end-user responsibility; servitized manufactures should look at reliability over an equipment lifetime, not for the contract length; there should be further investments for reliability contracts; there should be a global perspective within stakeholders to deliver reliability within service contracts effectively.
Key dependencies	To deliver advanced services and maintenance to customers, the followings are crucial: (i) the ability to plan and then adhere to that plan. (ii) alignment of commercial and motivational incentives. (iii) full awareness of the contract scope. (iv) consistent supplier performance on spares/repairs. (v) availability of resources, i.e. parts, information (e.g. responses to technical queries) and other relevant services (e.g. paint shop).
Key changes	To deliver advanced services and maintenance to customers, the following key changes are identified for an ideal contract: (i) to centralise inventory planning and forecasting across several contracts. (ii) to reduce contracts complexity regarding supply change, out-sourcing, contractual requirements, and procedures. (iii) to create a more flexible, customer-focused design team and approach. (iv) to implement an enterprise approach to data management.
Lesson learnt	To focus on lessons learnt from previous contracts when designing future maintenance contracts.
Culture	To achieve greater efficiency, the following key 'culture' aspects should be considered: (i) flexible staffing within the workforce. (ii) improving collaboration with different business sectors. (iii) creating a universal 'knowledge base system'. (iv) designing of tangible incentives (pension benefits and bonuses) to encourage a more global inclusive approach to working practice. (v) reducing the 'blame culture' and taking a more pragmatic approach to issues. (vi) reducing restrictions on individuals supporting other operational areas may not be within their primary role.

In the next step, the TES framework for through-life service provision is adopted to specify the As-Is state of technologies and capabilities required to deliver advanced service offerings. In the next step, based on the survey results on I-4.0 deployment and literature review on I-5.0, a recommended phased roadmap towards the desired future state is defined. The roadmap details three chronological phases. Phase 1, short-term, 0-5 years, Phase 2, medium-term, 5-10 years, and Phase 3, long-term, 10-15 years projection plan. The technological mapping is presented using a traffic light system approach. Red (1) no implementation and long-term plan for future advancements, Amber (2) base implementation and medium-term plan for future advancements, Green (3) full implementation and short-term plan for future advancements.

The results for As-Is state are presented in Table 3. Service ‘offerings’ from basic service to advanced service provisions are also included. The survey shows that the majority of the As-Is state in this section of the framework is either Green or Amber. To improve the amber requirements, further integration within the business is required. Moreover, the As-Is analysis has identified most of the ‘knowledge’ requirements as Green. However, ‘knowledge of customer operations’ is recognised as the only area for potential improvement.

Furthermore, the majority of As-Is state for ‘Tools’ are either Green or Amber. The key areas identified from the analysis that could be used for improvements lie around the decision optimisation and decision-making models behind them. The analysis of ‘technology’ requirements are provided in Table 4. Some of the technologies such as DT, AR and 3D-printing are developing technologies, whereas, Robotics and Cloud computing are under development as part of future projects. Finally, the main opportunities identified for ‘fundamental’ improvements focus around data, mind-set, and supply chain and logistics. Mind-set improvements come from further structuring the workforce from the product focus to the service focus PSS.

5. Conclusion

This study investigated the current state of I-4.0 implementation in digital servitization in the aerospace sector. Moreover, the I-5.0 technological enablers for future advanced service provisions are identified. Following the literature review and the survey output, the summary of short, medium, and long-term recommended roadmap are summarised in Table 4. The recommendations are categorised into technology, culture, and organisational elements. This study highlighted that I-5.0 mission is to ensure technologies and innovations support societies. Businesses should promote approachable ecological and social values. Advanced technologies for service provision should deliver sustainable solutions. Identifying skill gaps and providing training for using new technologies are vital. Fulfilling human safety, integrity and values in a collaborative human-robot workplace is crucial. Further, validation for the recommended roadmap is essential by conducting a comprehensive literature review and sending the survey to a larger group from different industrial sectors.

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Table 3. Survey outcome: As-Is readiness level of advanced service provision using ATI framework

PSS categories	Purely products		Product-oriented		Use-oriented		Result-oriented		Purely service	
	Basic services		Preventive and Corrective Maintenance		Predictive Maintenance		Real-Time Condition Based Services		Advanced As-A-Service Provision	
Offerings	- Breakdown response	3	- Scheduled MRO	3	- Reliability centred Maintenance (RCM)	2	- Condition-based services	3	- Other asset and business management	2
	- Insurance inspections	3	- Inspections (time-based)	3	- Diagnostics and emerging prognostics	2	- IVHM	2	- Availability/Capability as a service	3
	- Upgrades	3	- Planned repairs	3			- Real-time data	2	- Fleet/ Asset management	2
	- Spare Parts	3							- Maintenance planning	3
									- Operations planning	2
Knowledge	- In-service issues	3	- Requirements for basic in-service use	3	- Knowledge of Use	3	- Diagnostics	3	- Product design and functionality	3
	- Means of repair	3	- Product life/hours of in-service use	3	- degradation and failures	3	- Prognostics aligned to failure	3	- Customer business operations	2
	- Repair techniques	3			- Knowledge of Repair	3	- Degradation mechanisms	3		
	- Spares	3								
Tools	- Maintenance manual			3	- Common data and interoperability standards					2
	- Inspections report			2	- Degradation/ deterioration models					2
	- Issues databases			3	- Library of standards					3
	- Repair manuals			3	- Uncertainty models					2
	- Defect reports			2	- Optimisation tools					2
	- Logbooks			2	- Repair methods					3
Technologies	- Standards			3	Technologies required to deliver advanced service capabilities and support new business models:					
	- Prescribed tools and equipment for inspections			3	- Augmented Reality and wearables					2
	- Testing technologies			3	- data Analytics and algorithms					2
	- Repair technologies			3	- advanced and smart sensors					2
	- Maintenance planning			3	- Internet of Service Things					2
	- Maintenance management platforms			3	- Robotics and co-bots					1
					- Cloud computing					1
					- Mobile devices					2
					- Digital Twins					2
					- 3D- printing					2
Fundamentals	- Intellectual property and security of data									3
	- Skills, Standards and infrastructures									3
	- Data sharing and quality of data									2
	- Supply chain and logistics									2
	- Data ownership									2
	- Regulations									3
	- Mind-set									2

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Table 4. A phased roadmap for high-value service provision systems to achieve I-4.0 and I-5.0 capabilities.

Roadmap	Recommendations		
Categories	Short-term (Industry 4.0)	Medium-term	Long-term (Industry 5.0)
Technology	- Cloud computing - Big data analytics - Virtual simulation and testing (Digital Twin) - Mass customization for servitization - Cyber-physical system/ IoT - Augmented Reality Solutions - Data visualisation technology -Self-maintenance/ Automation	- Big data management - Digital threads (live sensors) - Multi-level CPS - Artificial intelligence - Real-time fleet monitoring - Mission reliability optimiser - Maintainability optimiser - AR, VR and mix-reality for training and inclusiveness - Informed deep learning	- Edge computing - Hybrid human-DT workspace - Biosensors and networked sensors - Smart dust for autonomous servitization - Human-CPS - Causal artificial intelligence - Secure and energy-efficient AI - Hydrogen and Power-to-X technologies - Human assistance cobots - Self-repairing and traceable material
Culture	- Secure data sharing - Industrial robots	- Universal knowledge-based data - Collaborative workforce	- Human-AI decision support systems - 'No Blame' culture and dignity at work
Organisational	- Design for 'X' communication structure - Smart warehousing/ logistics - Smart spare parts management	- Integrated end-to-end planning and real time execution - Centralised supply chain and Logistics visibility - Continuous ethical improvement	- Up-skilling digital competencies - Workers' mental and physical strain and stress tracking - Integration of renewable energy sources - Sustainable/ smart supply chain mobility

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