



**HAL**  
open science

# Towards a Comparative Data Value Assessment Framework for Smart Product Service Systems

Lennard Holst, Volker Stich, Günther Schuh, Jana Frank

► **To cite this version:**

Lennard Holst, Volker Stich, Günther Schuh, Jana Frank. Towards a Comparative Data Value Assessment Framework for Smart Product Service Systems. IFIP International Conference on Advances in Production Management Systems (APMS), Aug 2020, Novi Sad, Serbia. pp.330-337, 10.1007/978-3-030-57997-5\_39 . hal-03635653

**HAL Id: hal-03635653**

<https://inria.hal.science/hal-03635653v1>

Submitted on 30 Jun 2023

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License

# Towards a Comparative Data Value Assessment Framework for Smart Product Service Systems

Lennard Holst<sup>1</sup>, Volker Stich<sup>1</sup>, Günther Schuh<sup>1</sup>, Jana Frank<sup>1</sup>

<sup>1</sup>Institute for Industrial Management at RWTH Aachen University,  
Campus-Boulevard 55, 52074 Aachen

**Abstract.** This paper contributes to an assessment framework for valuing data as an asset. Particularly industrial manufacturers developing and delivering Smart Product Service Systems (Smart PSS) are comprehensively depended on the business value derived by processing data. However, there is a lack in a framework for capturing and comparing the Smart PSS data value with the purpose of increasing the accountability of data initiatives. Therefore a qualitative data value assessment approach was developed and specified on Smart PSS, based on an industrial case study research.

**Keywords:** Data Value, Data Value Assessment, Smart Product Service Systems, Case Study Research

## 1 Introduction

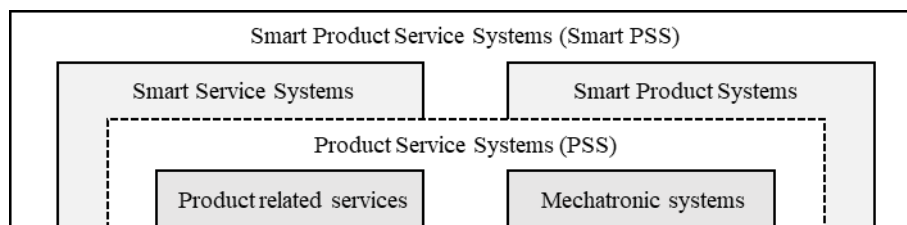
The most valuable companies these days regarding their market capitalization are internet and technology companies with almost no physical assets [1]. This determines the high intangible value and the deep economic impact of intangible assets, especially of data in the digital age. Throughout this paper we use the terms “data” and “value” as generic contiguous terms, comprising the assumption that data (symbols and signs) generate a contextual monetary value added within specific use cases. This assumption is conform to the DIKW pyramid, which describes data as the basis for obtaining information, knowledge and wisdom [2]. The access to data and the ability to use it properly are becoming key competitive factors and justify the need for the digital transformation of established business models [3]. For many years manufacturing companies are trying to adapt their established transactional business models being able to offer integrated solutions for their customers [4, 5]. In the early stages manufacturers designed and delivered services accompanying their products, creating so-called Product Service Systems (PSS) [6]. With the rise of digital technologies, falling costs for sensors and their connection via increasingly powerful, internet-capable networks known as the industrial internet of things (IIoT) these PSS are transforming to Smart Product Service Systems (Smart PSS) [7]. In Smart PSS data generation and evaluation are the binding components and the main drivers for engineering smart services and new digital business models around a smart product that delivers constant usage data. Whereas in the old transactional business, data was mainly generated within the operational process

and stored in intra-divisional silos or historically grown IT system landscapes [3], smart products are delivering an entirely new data-based insight into the usage phase. Thus smart products enable manufacturers to understand their customers' behavior and needs almost in real-time, offering the chance for a comprehensive customer-centric business orientation [3, 8]. However, observing Smart PSS manufacturing firms at every scale, there is an *overarching difficulty deriving, measuring and communicating value from specific digital initiatives* [9]. This leads to a two-sided problem: From an internal perspective, investments in digital product or service initiatives like e.g. the retro-fitting of products in operation with sensor technology are intensively discussed, whether it should be given away for free instead of being sold with a margin [10]. From a market perspective this might lead to the assumption that Smart PSS manufacturing firms are highly underrated. According to the current valuation and balancing standards, physical assets and future cash flow are valued in particular. Realized or potential values from data, that also need to be considered as assets [11], are attributed indirectly, if at all [12]. Although various methods for data valuation have been discussed in research for several years, none has yet established itself as a practicable market standard. Therefore this research focuses on a data value assessment framework for Business-to-Business (B2B) Smart PSS manufacturing firms, as they are already today particularly dependent on the business value added by data generation and usage.

## 2 State of Research

### 2.1 Smart Product Service Systems

The integration of ICT technology in PSS can be described as a digital transformation towards Smart PSS, enabled by embedded micro-devices, software technology and internet-capable interfaces [13]. Smart PSS are defined by (1) a high degree of autonomy and real-time reactivity, (2) a strong customer-centricity, (3) the interchangeability during the operation phase, (4) innovative business models and (5) interconnected components [13, 14]. All of the given attributes either generate or inevitably depend on a constant stream of usage data. An example of the Smart PSS complexity (Figure 1) and its immanent data value is the offering of printing machines as a subscription. Due to usage and benchmark data, the industrial manufacturer is able to offer guaranteed performance increases in a pay-per-print model, growing its business along with the customer [8].



**Figure 1.** Composition of Smart PSS based on [13, 14]

- Product related services: *e.g. traditional maintenance services*
- Mechatronic systems: *e.g. car brake systems*
- Product Service Systems: *e.g. installation and implementation of a machine*
- Smart Service Systems: *e.g. machine learning supported spare part orders*
- Smart Product Systems: *e.g. distance control assistants (cyber-physical)*
- Smart Product Service Systems: *e.g. printing machines, sold as a subscription*

## 2.2 Data Valuation Frameworks

In research literature, there are various approaches to the valuation of data, uniformly demanding the consideration of data as an asset with a disclosable business value. The following given research approaches are shortly described and assessed for their practicability in the research context: Already in 1999 Moody and Walsh [11] considered data, respectively information derived from data, as a “valuable but unvalued asset”. Based on *7 laws of information* they examined the three major asset paradigms in accounting theory: *Cost* (Or Historical Cost), *Market* (Or Current Cash Equivalent) and *Utility* (or Present Value). Although describing the pros and cons of the paradigms in the context of data valuation and developing general principles and ideas for valuing data, they claim themselves for not providing a complete methodology. Brennan et al. [15] developed and executed a general, survey based approach for a data value assessment. The proposed data value dimensions *Operational Impact*, *Dataset Replacement Costs*, *Competitive Advantage*, *Regulatory Risk* and *Timeliness* served as an important orientation, but are not sufficient for a practicable procedural method solving the issue of deriving and communicating data value on a comprehensive practice-oriented level. Laney [16] developed an indicator approach for valuing data, proposing three foundational measures *Intrinsic Value*, *Business Value* and *Performance Value* and three financial measures *Cost Value*, *Market Value* and *Economic Value*. Formulas are presented that can be used to calculate the respective values. However, the work does not provide any information on how the formulas can be quantified in practice. Within this paper the definition of the “contextual monetary value added by data” is based on the preliminary work of Zechmann and Moeller [17] who developed a comprehensive usage based valuation approach, even applied in Smart PSS related case studies. However, already Moody and Walsh [11] stated that usage based valuation methods are time consuming and costly. Therefore they are considered to be unable serving as a standardized and comparative data value assessment framework. The same bottom line applies to the Data Value Map approach by Nagle and Sammon [9] that is particularly designed as a workshop and visualization concept to map data initiatives.

## 3 Research Process

In order to develop a data valuation assessment for Smart PSS manufacturing firms a case-based research method according to Eisenhardt was chosen [18]. The method allows a practice-oriented research process consisting of eight steps, listed in Table 1 [8, 18]. F

**Table 1.** Case study process and implemented research activities, based on [18]

Process step	Proposed activities	Implementation during the research process
I. Getting Started	Defining the research question	What are the Smart PSS requirements regarding data valuation and its assessment process?
II. Selecting Cases	Specifying population	Examination of 7 Smart PSS manufacturers with a diverse product and (digital) service portfolio in the branches printing, milling, laser cutting, medical devices, industrial tools and sensor technology
III. Crafting Instruments	Combining data collection methods	Telephone and in-person interviews, workshops, internal documents, secondary source documents
IV. Entering the Field	Overlapping data collection and analysis	Two iterations: 1. Deriving conceptual requirements 2. Transferring results into an assessment framework
V. Analyzing Data	Within-case analysis	Ranking present data streams to their perceived value (context of use, data quality, monetizing effects)
VI. Shaping Hypothesis	Iterative tabulation of evidence	Conclusion after 2 iterations: using 6 main requirements and a 6 step assessment approach
VII. Enfolding Literature	Comparison with conflicting literature	Comparison with existing data valuation approaches and Smart PSS literature presented in section 2.2
VIII. Reaching Closure	Theoretical saturation	Observed flattening curve regarding knowledge gain

## 4 Results

### 4.1 Requirements Derived from the Case Studies

The following Table 2 ranks the requirements towards a data valuation method from the first iteration of the case study research, according to the utility analysis carried out with the Smart PSS manufacturing firms:

**Table 2.** Requirements towards a data valuation method

Ranked requirements	Description of the specific requirement
R <sub>1</sub> : Data Catalogue	A data catalogue with ex-ante formulated valuable data streams
R <sub>2</sub> : Data Quality and Attributes	Data quality requirements are depended on the use case and should be linked upfront with certain tolerance levels for specific use cases
R <sub>3</sub> : Standardization Possibilities	Since individual, usage based valuations are not suitable for standardization, a context/use case catalogue needs to be given ex-ante A neutral third party entity is needed serving as auditor
R <sub>4</sub> : Hybrid Valuation Method	The data value captured needs to integrate the dimensions <i>monetization</i> and <i>indirect, usage value add</i>
R <sub>5</sub> : Customer Insights*	Customer Insights are considered to have the highest impact on the present and future business value in Smart PSS

R<sub>6</sub>: Qualifying Date                      When the data value assessment is carried out there needs to be a strong separation between the present and the future data value

\* Definition of Customer Insights: If customer data from various sources is systematically collected, interpreted and used to derive findings for adapting business processes.

## 4.2 General Framework for a Data Value Assessment

The following Table 3 presents the assessment steps that were developed in the second iteration of the case study analysis. The fundamentals were the requirements derived from the first iteration. The assessment steps are therefore linked to the requirements, depicted in section 4.1 and marked by R<sub>x</sub>. In addition, the responsibility column differentiates between the responsible authorities, since Smart PSS manufacturing firms are unable to perform a comparative data value assessment on their own. Over and above that there was a demand for a neutral third party serving as a data value auditor (cf. R<sub>3</sub>).

**Table 3.** General assessment steps for a data valuation framework

Assessment step	Description of the assessment step	Responsibility
S <sup>1</sup> : Setting up the data catalogue (R <sub>1</sub> , R <sub>3</sub> , R <sub>5</sub> )	Initially determining the most valuable data streams for the considered system	Third party / Auditor
S <sup>2</sup> : Setting up the use case catalogue (R <sub>3</sub> , R <sub>4</sub> )	Defining a catalogue of relevant use cases for the data streams set up in S <sup>1</sup>	Third party / Auditor
S <sup>3</sup> : Establishing data attributes and threshold values (R <sub>2</sub> )	Setting up data attributes, linking them to use cases Data quality threshold values for the specific use cases	Third party / Auditor
S <sup>4</sup> : Preliminary assessment and software tool support (R <sub>6</sub> )	Smart PSS manufacturing firms must be guided through a semi-automatic assessment of S <sup>1</sup> - S <sup>3</sup>	Smart PSS manufacturing firms
S <sup>5</sup> : Applying a hybrid data value method (R <sub>4</sub> , R <sub>6</sub> )	Combining cost, market and usage based valuation approaches in a standardized data value method	Third party / Auditor
S <sup>6</sup> : Final assessment (R <sub>3</sub> )	Assessment for examination of the results from S <sup>4-5</sup>	Third party + Smart PSS

## 4.3 Smart PSS Specified Framework for a Data Value Assessment

This section specifies the derived assessment steps S<sup>1</sup>-S<sup>3</sup> of section 4.2 on Smart PSS, which was an additional part of the second iteration within the case study research process. The assessment steps S<sup>4</sup>-S<sup>6</sup> are prospect to further development stages and research.

**S<sup>1</sup> Setting up the data catalogue:** Within the case study research process Customer Insights were determined to be the most important, data driven value provider to Smart PSS. Therefore a data catalogue for Customer Insights was developed, initially gathering the most valuable data streams with the option of implementing a data stream significance ranking and readjustments in case of further examinations. The data catalogue was structured alongside 4 customer journey phases: (1) *Attention phase* with customer-specific data streams like store visits, website visits, conversations with chat-bots, call

center activities, social media appearances etc. (2) *Acquisition phase* with data streams like customer master data, sales data from field representatives, sales data from digital distribution channels etc. (3) *Usage phase* with data streams like usage and performance data in real-time or discrete, data from self-service customer portals, data from service tickets, data from remote service diagnostics, complaint data, data from blogs and forums etc. (4) *Loyalty phase* with data streams like the purchase history, internal and external market research data etc.

**S<sup>2</sup> Setting up the use case catalogue:** The data streams from S<sup>1</sup> will be individually linked to fixed use cases. This step is the essential part of the data value generation chain to derive a contextual monetary value added. In order to develop a practicable use case catalogue an aggregated level for providing the use cases was chosen. A longlist was set up, including various use cases like *increasing customer satisfaction, deriving marketing measures, submitting individual customer offers, ensuring that customer use offerings correctly and receive a return on investment, quantify the perceived customer value, improve the customer experience, adjust pricing schemes, increase performance of services and products, direct selling of the data asset etc.*

**S<sup>3</sup> Establishing data attributes and threshold values:** For each use case an initial, standardized set of data attributes needs to be classified. Threshold indicators are implemented within the attribute *data quality criteria* and can be checked in the preliminary assessment S<sup>4</sup> by the Smart PSS manufacturing firm. The attributes are *Monetization* (direct, indirect, realized in the past vs. in a 3 year forecast with a probability of occurrence), *Data Sourcing* (costs for sourcing and mining the data), *Data Processing and Analysis* (need and ability for analysis, occurred costs,), *Data Quality Criteria* (accuracy, quantity, transfer rate, vulnerability, accessibility etc., each criteria with an initial threshold value) *importance for business model and decisions* (criticality, importance for decision makers).

**S<sup>4</sup> Preliminary assessment with tool support:** To deliver the assessment steps S<sup>1</sup>-S<sup>3</sup> in a practicable setting a semi-automated tool, including the data catalogue and use cases as well as the possibility to link data attributes is currently being developed.

**S<sup>5</sup> Applying a hybrid data valuation:** The hybrid data valuation approach consists of linking the three accountability paradigms (cf. section 2.2) via S<sup>1</sup>-S<sup>3</sup> and is currently being examined with business valuation and auditing experts.

**S<sup>6</sup> Final assessment:** Within the final assessment, the information given by the Smart PSS manufacturing firm in S<sup>4</sup> on the current abilities to realize present and future data value need to be audited. To standardize the assessment steps in order to thrive a comparative Smart PSS individual data value a VDI guideline will be set up in the research project *Future Data Assets*.

## 5 Conclusion and Further Research

Based on the derived requirements towards a comparative data value assessment, determined during the practice-oriented case study research process, a new and more standardized data value assessment logic was developed and initially specified on Smart PSS. Therefore existing data valuation methods can serve as fundamentals but

are suggested to be put in a more comparative framework by default, respectively fixed data streams, data usage and data attribute dimensions. A third party accompanied data value assessment can help Smart PSS to better evaluate and communicate the benefits of digital initiatives with the various internal and external stakeholders.

Concerning the presented research status further research activities regarding an easy-to-use software tool support and an integrated hybrid data valuation method need to be carried out to complete and standardize a comparative assessment framework. Expanding the perspective, the topic data valuation was found to be relatively uncharted. Thus, forcing researchers and practitioners to work closely together on practicable solutions to communicate the data value internally and externally, since the data economy across all branches is rapidly gaining momentum and business models are becoming increasingly dependent on the value derived by data usage.

## 6 Acknowledgement

The research and development project *Future Data Assets* that forms the basis for this report is funded within the scope of the ‘Smart Data Economy’ technology program run by the German Federal Ministry for Economic Affairs and Energy (BMWi) and is managed by the DLR project management agency. The authors are responsible for the content of this publication.

### References

1. PwC: Global Top 100 companies by market capitalisation. <https://www.pwc.com/gx/en/audit-services/publications/assets/global-top-100-companies-2019.pdf> (2019). Accessed 1 April 2020
2. Rowley, J.: The wisdom hierarchy: representations of the DIKW hierarchy. *Journal of Information Science* (2007). <https://doi.org/10.1177/0165551506070706>
3. Porter, M., Heppelmann, J.: How Smart, Connected Products Are Transforming Companies. *Harvard Business Review* 93(no. 10 (October 2015)), 97–114. <https://hbr.org/2015/10/how-smart-connected-products-are-transforming-companies> (2015)
4. Kowalkowski, C., Gebauer, H., Oliva, R.: Service growth in product firms: Past, present, and future. *Industrial Marketing Management* (2017). <https://doi.org/10.1016/j.indmarman.2016.10.015>
5. Oliva, R., Kallenberg, R.: Managing the transition from products to services. *Int J of Service Industry Mgmt* (2003). <https://doi.org/10.1108/09564230310474138>
6. van Halen, C., Vezzoli, C., Wimmer, R.: Methodology for product service system innovation. How to develop clean, clever and competitive strategies in companies (2005)



7. Chowdhury, S., Haftor, D., Pashkevich, N.: Smart Product-Service Systems (Smart PSS) in Industrial Firms: A Literature Review. *Procedia CIRP* **73**, 26–31 (2018)
8. Schuh, G., Frank, J., Jussen, P., Rix, C., Harland, T.: Monetizing Industry 4.0: Design Principles for Subscription Business in the Manufacturing Industry. In: 2019 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC). 2019 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC), Valbonne Sophia-Antipolis, France, 17.06.2019 - 19.06.2019, pp. 1–9. IEEE (2019)
9. Nagle, T., Sammon, D.: The Data Value Map: A Framework for Developing Shared Understanding On Data Initiatives. In: Proceedings of the 25th European Conference on Information Systems (ECIS), pp. 1439–1452 (2017)
10. Möller, D.: Guide to Computing Fundamentals in Cyber-Physical Systems. Concepts, Design Methods, and Applications. *Computer Communications and Networks*. Springer International Publishing, Cham, s.l. (2016)
11. Moody, D.L., Walsh, P.: Measuring the Value Of Information - An Asset Valuation Approach. In: Proceedings of the Seventh European Conference on Information Systems, ECIS 1999, Copenhagen, 1999
12. Leatherberry, T., Mears, R.: Data as an Asset: Balancing the Data Ecosystem. [http://mitiq.mit.edu/IQIS/Documents/CDOIQS\\_201077/Papers/03\\_09\\_4C-1.pdf](http://mitiq.mit.edu/IQIS/Documents/CDOIQS_201077/Papers/03_09_4C-1.pdf) (2010). Accessed 3 April 2020
13. Abramovici, M., Göbel, J.C., Neges, M.: Smart Engineering as Enabler for the 4th Industrial Revolution. In: Fathi, M. (ed.) *Integrated systems: innovations and applications*, pp. 163–170. Springer, Cham (2015)
14. Kuhlenkötter, B., Bender, B., Wilkens, U., Abramovici, M., Göbel, J.C., Herzog, M., Hypki, A., Lenkenhoff, K.: Coping with the challenges of engineering smart product service systems - Demands for research infrastructure. In: Proceedings of the 21st International Conference on Engineering Design (ICED17), Vol. 3: Product, Services and Systems Design, Vancouver, Canada, 21.-25.08.2017., 87, 3
15. Brennan, R., Attard, J., Petkov, P., Nagle, T., Helfert, M.: Exploring Data Value Assessment: A Survey Method and Investigation of the Perceived Relative Importance of Data Value Dimensions. 21st International Conference on Information Systems (ICEIS) (2019). <https://doi.org/10.5220/0007723402000207>
16. Laney, D.B.: *Infonomics*. Taylor and Francis, London (2017)
17. Zechmann, A., Möller, K.: Finanzielle Bewertung von Daten als Vermögenswerte. *CON* (2016). <https://doi.org/10.15358/0935-0381-2016-10-558>
18. Eisenhardt, K.M.: Building Theories from Case Study Research. *The Academy of Management Review* **14**, 532 (1989)