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RÉSUMÉ – La littérature consacrée aux systèmes produits-services (SPS) met en évidence différentes conceptualisations des SPS selon les disciplines, et donc une fragmentation scolastique des terminologies et méthodologies. En s'appuyant sur une approche de linguistique appliquée, ce travail apporte à ces concepts et méthodes une cohérence générale à travers l'étude de l'intention humaine que sous-tendent tous les SPS. Les données empiriques sont collectées à partir de SPS de robots collaboratifs.

MOTS-CLÉS – Système produits-services, robot collaboratif, linguistique fonctionnelle systémique, modèles d'affaires, méthodologie de recherche

CORDEIRO (Cheryl Marie), « Manifestation of intent in product-service systems. A study of type of sensing in collaborative robots »

ABSTRACT – Review type studies of product-service system (PSS) indicate different conceptualisations of PSSs across disciplines, that lead to perceived scholastic fragmentation of terminology and methodology. This study brings integral coherence to concepts and methods in PSS through an applied linguistics approach of the study of human intent underlying all PSSs. Empirical data is collected from collaborative robot PSSs. The aim of the study is to illustrate coherence in fragmentation of perspectives.

KEYWORDS – Product-service system, collaborative robot, systemic functional linguistics, business models, research methodology

# MANIFESTATION OF INTENT IN PRODUCT-SERVICE SYSTEMS

A study of type of sensing in collaborative robots<sup>1</sup>

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## INTRODUCTION

The business model development of a traditional manufacturing company from product focused to that of an integrated product-service offering has broadly been termed ‘servitization’ in services and technology management research (Cavalieri & Pezzotta, 2012; Baines *et al.*, 2007; Vandermerwe & Rada, 1988). The idea of shifting from products to services was introduced already in the 1960s by Becker (1962), who together with other scholars within the same decade, had proposed the rise of services economy where people would not only purchase/consume products but the intangible benefits surrounding product consumption (Levitt, 1969; Fuchs, 1965, 1968). With advancing automation technologies confluencing with that of the developments of information communication technologies (ICTs) in the past decades, the intangibles surrounding product consumption has come into greater focus, both in business models and in academic literature. Customers today prefer

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purchasing customised solutions rather than only products. This solution package has mostly been referred to as a product-service system (PSS) (Tukker & Tischner, 2006a, 2006b). As a means for how to study a PSS that encompasses complex processes pegged at different levels of hierarchy, a working definition of a PSS was proposed in a 1999 report commissioned by the Dutch ministries of Environment (VROM) and Economic Affairs (EZ) as:

...a marketable set of products and services capable of jointly fulfilling a user's need. The PS system is provided by either a single company or by an alliance of companies. It can enclose products (or just one) plus additional services. It can enclose a service plus an additional product. And product and service can be equally important for the function fulfilment. The researcher's need and aim determine the level of hierarchy, system boundaries and the system element's relations. (Goedkoop, van Halen, te Riele & Rommens, 1999:18).

As technology advances and converges in function, a more modularised customer centric approach can now be taken when it comes to product-service offerings that at the same time allows for manufacturing companies to remain competitive by differentiating themselves on the market (Fadeti *et al.*, 2017; Gebauer *et al.*, 2011). The composite character of a PSS as connecting product-technology with social-technical systems, have seen several ontological and epistemological studies addressed by various scholars (Beuren, *et al.*, 2013; Baines *et al.*, 2007; Goedkoop *et al.*, 1999). Although not always having positive environmental impact (Tukker & Tischner, 2006a), for some scholars, a PSS contains an element of environmental symbiosis and sustainability, defined by either life cycle management strategies or lower environmental impact of manufacturing systems (Kjaer *et al.*, 2016; Manzini & Vezzoli, 2003; Goedkoop *et al.*, 1999).

Academic journal publications situate the PSS concept and framework of study at the intersection of the disciplines of Business Management (that includes Business Service and Decision Science), Engineering and Environmental Science (Annarelli *et al.*, 2016). The past decade's scholastic literature also indicate that the PSS concept has largely been investigated from the tripartite perspective of (A) *product-oriented* PSS, (B) *use-oriented* PSS and (C) *result-oriented* PSS (Annarelli *et al.*, 2016; Sakao *et al.*, 2009; Baines *et al.*, 2007; Goedkoop *et al.*, 1999). What seems lacking in the field of PSS research, acknowledged by scholars are theoretical frameworks and survey methodologies that can direct scholars and practitioners towards

a cohesive future methodologies framework of analysis and investigation (Tukker & Tischner, 2006a, 2006b). Scholars have also found that studies on PSSs are often exploratory in nature, employing a quantitative (survey) method of inquiry, else describing and analysing via the use of case studies. Different terminologies have also been used to describe similar concepts in PSS studies that leads to fragmented conceptualisations and theory (Boehme & Thomas, 2013). In particular, practical applications and theory testing of characterised PSS within the academic literature needs to be done, which can be challenging for the study of PSSs whose applicability can cross different fields (Annarelli *et al.*, 2016).

Yet within this fragmentation and perceived lacking of theoretical and methodological coherence in the study of PSSs, lies the human factor of *Intent*, as reflected in language use in the discourse of the processes surrounding a PSS. This contribution views Intent, defined as ‘aim or purpose’ to be the coherent element that runs through the tripartite conceptualisation of the PSS. Intent could be said to be reflected implicitly in the PSS literature. The purpose of this study is to make the element of human Intent explicit, in illustration that the tripartite characterisation of PSS is interrelated and construes the experience of a PSS as indeterminate and fluid.

Intent is often put forth in language in use, whether in negotiations on designing or implementing a PSS. Intent in the processes of the PSS could be seen as containing multiple nuances, being one of the primary motivators of producing, using and developing a PSS. It is a human factor element that is present in the tripartite perspective of the PSS. In addition, Intent is reflected in the larger contextual environment of the ecology of the PSS by the material processes of human action.

This contribution proposes that uncovering Intent behind the conceptualisation, production and use of a PSS can help scholars and practitioners towards a more holistic understanding of the processes of PSS development. Uncovering Intent can be accomplished via an applied linguistics analysis on the discourse surrounding the processes of the PSS.

The main research questions addressed in this contribution are:

- How can Intent, currently reflected implicitly in the tripartite characterisation of a PSS be made explicit in illustration as a core element of coherence in a PSS?

- How can Intent in PSSs be used to complement current state-of-art understanding of its development processes?

Taking on a systems theory perspective in international business studies and organization science, this contribution leverages the findings of studies on PSS conceptualisation and framework (Annarelli *et al.*, 2016; Geum, Lee, Kang & Park, 2011; Baines *et al.*, 2007; Goedkoop *et al.*, 1999), and complements data to the field via primary and secondary data. The purpose of this study is to conceptualise and model an integral perspective of the PSS framework, in complement to the general tripartite PSS framework currently reflected in the literature, the binding element of coherence being Intent. The integral model proposed aims at illustrating that the complex processes reflected in a PSS can be investigated in a systematic systemic manner, towards a holistic perspective and understanding of the processes and development of a PSS. The PSS study example is collaborative robots, used for various applications and purposes across industrial sectors from electronics, healthcare, food and beverage and entertainment.

The method of data analysis is an applied linguistics framework based on systemic functional linguistics (SFL) onto the retrieved and transcribed videos of recorded interviews. A concordance software, AntConc (Anthony & Baker, 2015a, 2015b), is used to facilitate accurate data mining and analytics in the created corpus. The concordance results are then analysed using SFL's transitivity analysis framework, in particular, Type of Sensing in mental transitivity processes in order to uncover Intent. The applied linguistics method is further exemplified in the sections below.

## I. LITERATURE REVIEW

### I.1. CONCEPTUALISATION OF THE PRODUCT-SERVICE SYSTEM

Since its initial conception in 1999 by Goedkoop *et al.*, product-service system (PSS) characterisation and conceptualisation is a business strategy established on the value proposition that focuses on user needs

rather than only product (Baines *et al.*, 2007). In practice, this meant an increase in services in the form of maintenance or repair than supplying the customer with a new product. This move extends the life cycle of a product where parts of products are also replaced only when needed. New technologies offered opportunities for improved products and services (Vandermerwe & Rada, 1988) and new business models continue to form based on this paradigm shift product oriented sales to reuse of product and services of product (Tukker, *et al.*, 2006; Stahel, 1993, 1982). Comprehensive review type articles of PSS studies have been conducted in the disciplines of Engineering and Environmental Science (Annarelli *et al.*, 2016), Applied Sciences and Industrial Ecology (Tukker, 2015) and Information Systems, Business Management and Engineering & Design (Boehm & Thomas, 2013). The most recent comprehensive PSS review paper is by Annarelli *et al.* (2016). In that review paper, the authors give an overview of the current knowledge of the PSS field of study in view of future research directions. Using access to an electronic database with subject areas defined by Scopus, their study included a systematic review of an initial retrieved 342 articles. Based on full text analysis of keywords, a final selection of 210 articles were selected from Scopus listed subject areas that included (i) Business, Management and Accounting, (ii) Decision Sciences, (iii) Environmental Sciences and (iv) Economics, Econometrics and Finance. The retrieved articles covered a period between 2000 and 2016. Using citation analysis, the authors retrieved another 14 articles dating between 1988 and 2016, giving a final set of 224 core articles (Annarelli *et al.*, 2016). Their study found that 113 (50%) of the papers do not report a definition of PSS, while 19 (8%) of the papers gave their own definition of PSS. Of the papers cited for PSS definition, the most referred to is by Mont (2002) and Goedkoop *et al.* (1999) with 28 times each, followed by Baines *et al.* (2007) with 23 times, and Tukker (2004) with 13 times. However, with reference to research design framework, it is Tukker's (2004) PSS tripartite typology presentation model of *product-oriented PSS*, *use-oriented PSS* and *result-oriented PSS* that remains most comprehensive and current in the literature. This has also been found in the review study conducted by Boehm and Thomas (2013), where the authors highlighted that business models were widely discussed in the Business Management literature with models presented for downstream market given by Wise and

Baumgarner (1999), although Tukker’s (2004) PSS model was quoted as most comprehensive. The main and subcategories that comprise a PSS as represented by Tukker (2004) is reflected in Figure 1. Tukker’s tripartite PSS framework that outlines the research perspective of how most studies of PSS have been designed, provides a useful framework in the PSS field, to which the study of human Intent from an SFL perspective can be jointly framed. The aim of this study is to complement the current PSS frameworks of study, broadening the knowledge base of current literature by uncovering human Intent as a cohesive thread that underlies the continuum of PSS study perspectives, from *product-* to *use-* and *result-oriented* PSSs.

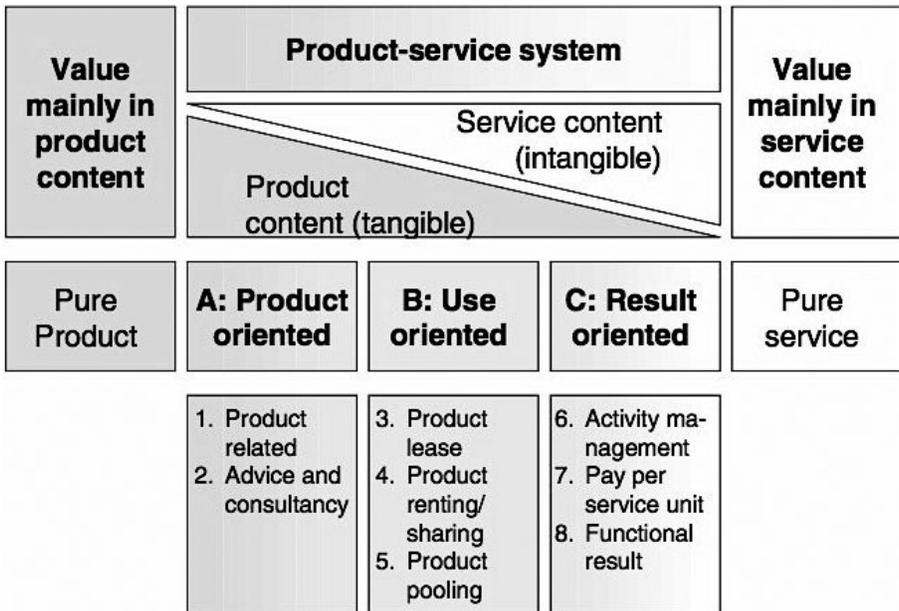


FIG. 1 – Main and subcategories of a product service system (PSS), as represented by Tukker (2004, p. 248).

According to Tukker (2004), while scholars tend to agree that the division of products and services remains undefined and perhaps context specific, the characterisation of PSS types (that in turn affect how PSSs are researched) fall broadly under:

1. *Product-oriented services.* In this PSS type, providers focus on the sales of the product and offer advice and consultancy services in relation to the product sold. The consultancy services provide a value-add for the customer. An example of which is a product introduced into a factory line, and the provider gives advice on how to optimise the logistics and supply chain management (SCM) of the new product as part of the production unit. This system leverages on the existing infrastructure and organizational structures in order to position the sales of the product, elaborating on current business systems (Tukker & Tischner, 2006a).
2. *Use-oriented services.* In this PSS type, the product is leased and the provider retains ownership of the product, often responsible for the maintenance, control and repair of the product through its life-cycle. Services under this system include renting, sharing or product pooling. These types of services can also bolster elaboration of business systems, the value-add sometimes occurring in the manner in which the product is available through leasing rather than direct purchase and ownership.
3. *Result-oriented services.* In this PSS type, the customer's needs are in focus in the manner of attention paid by the provider towards customisation of product. This could involve the provider, working closely with the customer, to conceptualise a novel solution needed to the current business system.

#### I.2. SUSTAINABILITY AS CORE ELEMENT IN A PRODUCT-SERVICE SYSTEM

Apart from the fragmented nature of the applications of the PSS that places a challenge on gaining a holistic, integrated view of PSS as a research stream, current literature also reflects intensive discussions within the academic circles on the element of sustainability in a PSS (Tukker, 2015). PSS developed as a research subject by researchers engaged with sustainability and business, due to that PSS considers final user needs and wants in the design process of a need-fulfillment systems. This shift in perspective from product to user during the systems design phase improved resource efficiency that in turn lowered the overall undesirable socio-environmental impact (Fadeyi *et al.*, 2017; Boons & Lüdeke-Freund, 2013; Tukker 2015, 2006a, 2006b; Goedkoop

*et al.*, 1999). Some scholars go farther to define the implementation of a PSS as having a lower environmental impact than traditional business models based on the understanding that system based solutions facilitate a different infrastructure due to product-service design and network relations (Hu *et al.*, 2012; Mont, 2002). The implementation of eco-efficient PSSs is widely bolstered by national and regional funding agencies such as research projects within the field of PSS and sustainability funded by the European Union (EU) under its Factories of the Future (FoF) PSS cluster projects (EU 2017). Despite the knowledge accumulated, there seems a consistent find that the design and implementation of the concept remains limited much due to that in most cases, such PSSs fall within the realm of ‘radical innovations’ that challenge existing physical and social infrastructures, coming to bear upon individual belief systems, current organizational cultures, corporate regulations and even dated digital infrastructures that hinder efficient operations (Ceschin, 2013; Vezzoli *et al.*, 2012; Tukker & Tischner, 2006a; Mont, 2002)

As a note on the use of words in concept definition, ‘sustainability’ in this contribution is understood as implying a certain autopoiesis of a system, wherein the system is able to sustain itself through a continuous dialogic of its internal processes (aligning its inherent potential towards future continued adoption and development) and external processes (being part of an ecology of systems). The use of the term here as such, has broader meaning implications than measurable variables of eco-PSSs.

### 1.3. COLLABORATIVE ROBOTS

Robots and automata have captured the creativities and espoused the inspirations of human beings since antiquity. Yet it was really in the past decades from about the 1950s onwards, spurred with the works of authors such as Robert Heinlein and Isaac Asimov, who were prolific and influential science fiction writers, that robots gained popularity. Reports by the International Federation of Robotics (IFR, 2016a, 2016b, 2016c) suggest a continued increase in robot installations across functions, across international markets. Although China is the largest robot market since 2013 with a continued dynamic growth, 2015 IFR statistics indicated that Europe seems to currently hold the highest robot density per 10,000 persons employed with 92 units, compared

with 86 in the Americas and 57 in Asia (IFR, 2016c). With the average global robot density at 69 units, the low density of robots for Asia could possibly be attributed to the overall differentiated developed economies of Asia. Japan and the Republic of Korea for example, are some of the more globally advanced countries in manufacture and use of robotics.

Collaborative robots (CRs) are a type of industrial robot designed to work alongside humans in a shared workspace (Probst *et al.*, 2015). This is currently a new frontier in industrial robotics because of the way in which CR redefines industrial robotics, division of labour and human-robot working spaces. In terms of products and services in the CR industry, Europe seems to take lead with Danish Universal Robots (UR) launching their CR range in 2009. The duo-armed YuMi by ABB, a European founded multinational enterprise (MNE) with 250,000 robots installed globally, was launched in April 2015 at the Hannover Fair, having first been conceived in 2007 within the organization (Bogue, 2016).

#### 1.4. COLLABORATIVE ROBOT PRODUCT-SERVICE SYSTEM

Due to that CRs are meant to operate in the same workspace as humans without safety cage barriers, the standards of safety features of CRs are highly regulated and strict. Most CRs are built in accordance to the International Organization for Standardization (ISO) safety standards that could be either national or regional specific, the ISO/TS 15066:2016 for example, that specifies safety requirements for collaborative industrial robots in supplement to ISO 10218-1 and ISO 10218-2 (ISO, 2016).

The congruent collaborations of public institutions and private organizations make the processes around a collaborative robot product-service system (CR PSS) an interesting example for an integral conceptualising of a PSS via the study of Intent that underlies a PSS. CR also allows for mass customisation from industrial robotics in a way that could not previously have been done in manufacturing processes. Being user-friendly and human oriented in design, some CR being equipped with facial expressions (e.g. Baxter and Sawyer, Rethink Robotics) and duo-arms (YuMi, ABB), it brings robotic technology to new market segments such as small to medium enterprises (SMEs). Due to its dexterity at being repurposed towards a different function, CRs can also cross from pure manufacturing functions to the entertainment (DJ YuMI, ABB) and

food industries (barista robot, Bubble Lab). As such, the cross-function, highly customisable CR can be seen as operating in a PSS.

## II. METHOD

### II.1. EMPIRICAL DATA COLLECTION

CRs are fairly novel in technology, the first being launched in 2008 by Danish UR (Business Wire, 2016). They also form a particular segment of automation products in total, which makes obtaining direct information from companies difficult. Table 1 shows the figures for the top eight robotics companies worldwide, known as the Big-8, based on number of installations (Trobe, 2016; Montaqim, 2015). Considering the qualitative methodology adopted for this study, as well as the novelty of the study of Intent in the PSS being investigated, it was more effective to retrieve secondary empirical data for analysis and insight into the CR PSS.

Fanuc	400,000
Yaskawa	300,000
ABB	250,000
Kawasaki	110,000
Nachi	100,000
Kuka	80,000
Denso	80,000
Epson	45,000
Adept	25,000

TAB. 1 – Top international robot companies, the Big-8, based on robots installed worldwide (Trobe, 2016). These numbers do not specifically reflect collaborative robots installed. UR's fast growing CR sales and statistics for example remains unreflected in the Big-8 figures.

In order to retrieve the data, a keyword search for “collaborative robots” in YouTube was used. The keyword search had a retrieval rate of over 97,000 results. The plethora of genres of CR related videos range from

documentaries, installation and programming (instructional) videos, demonstration of new features of existing CR products, to company marketing material. In order not to conflate the purposeful production or Intent of the video production (i.e. for product marketing or for science education) with the Intent of a CR PSS, the results were further filtered to reflect Intent in a CR PSS from a (i) producer perspective and (ii) customer/user perspective. The videos chosen for analysis include a form of producer and customer/user narrative that in turn is transcribed into texts for the purposes of analysis.

## II.2. MANAGEMENT OF RETRIEVED DATA

With current digital technologies and online platforms for information sharing, the more likely scenario in today's research context is that scholars and practitioners are faced with an overwhelming amount of data to be retrieved and systematically managed for analysis. Videos accessible for public viewing in this sense provide a rich source of data to be retrieve, analysed and cross-checked from the perspectives of different research paradigms.

In order to study the CR PSS, 20 corporate videos uploaded unto shared media platforms such as YouTube were selected to form a small corpus for text analysis. The videos retrieved were produced mostly by top CR producing and installing companies (the Big-8) such as Universal Robots, Fanuc, Yaskawa, ABB and Rethink Robotics. Each video was transcribed using modified standard orthography (MSO), following the Göteborg Transcription Standard (GTS) version 6.4 (Nivre *et al.*, 2004). Each video was transcribed at three levels in accordance to MSO GTS version:

- Ti. Text accompanying video upload
- Tii. Text appearing as subtitles or tags in the video and
- Tiii. Text as transcription of interviews with individuals in the videos

In the case of studying a CR PSS in an integral manner, corporate videos were chosen as a source for data for the following reasons:

1. Consistency of purpose in the video production. Most videos retrieved were produced for the main purpose of show casing new

models of CRs and their applications from the producer's perspective and/or showcasing the implementation of CRs in factories from the integrator/customer/user perspective. The retrieved data were selected based on their illustration of these various perspectives of individual actors within a CR PSS.

2. Concise information presentation. Most videos were concise, ranging between 3 to 5 minutes in length. The main purpose of which was to showcase interviews with individuals who had expert knowledge within the CR PSS either as producer, integrator or user of a CR. Gaining their perspective in terms of how they speak about CRs can in turn lend a multi-agent view of the CR PSS.
3. International scope. The retrieved data span different countries of CR PSS applications. The spanning of perspectives retrieved from actors of different countries and geographic regions gives the possibility to explore country/region specific CR PSS development and ideologies of implementation.
4. Multimodal source of data. Apart from the three levels of text analysis that these retrieved videos allow for, the dimension of visual analysis of paralinguistic features, spatial context, etc. can also be carried out as complementary facets of analysis, thus enriching insight into findings.
5. Open access data. The open access data allows for similar types of data to be collected, and compared either in parallel studies or longitudinal studies. It also allows for a corpus database to be developed for specific purposes and types of studies that when taken in their entirety of perspectives, gives a comprehensive view of the field of research interest.

### II.3. USE OF CONCORDANCE SOFTWARE

A corpus of texts was created with the MSO GTS transcriptions from the 20 videos retrieved. A concordance software, AntConc (Anthony & Baker, 2015a, 2015b), was used for data mining and analytics. In this sense, this study is corpus driven. AntConc is a freeware concordance program for Windows, Macintosh OS X and Linux. The software includes seven tools that allows for data mining and analytics to be carried out in the form of conducting word frequency listings, keyword-in-context searches, identifying both sequential and non-sequential patterns of use

for a specific word (clusters/N-Grams, word collocates), searching for statistically significant similarities/differences between texts and corpora (concordance plots) and making multi-modal comparisons using corpus linguistics methods. On condition of a standard applied transcription, a concordance software analysis is replicable.

The concordance software in this study was used as a means to organize texts and to bring statistically significant data to foreground, such as the most frequent use of various types of verbs (adjunct, transitive, intransitive) that help identify semiotic processes in the next stage of data analysis. AntConc was also used in its frequency word list, word collocation and concordance plot functions to help identify which transcribed texts had the highest concentration of use of specific words such as *with*, *can* and *are*, that depending on collocation and use in context, might illustrate Intent in both the design and implementation / use of a CR PSS. Texts with most relevant examples for Intent are used as Text Examples in this article.

#### II.4. SYSTEMIC FUNCTIONAL LINGUISTICS: TRANSITIVITY ANALYSIS

Systemic functional linguistics (SFL) views language as a social semiotic, where language is a systemic resource/tool for meaning making in context. Developed by Michael Halliday (Halliday & Matthiessen, 2014; Halliday, 1978) who developed further the notion of language as a system from the works of Firth (1957), the central organizing dimension of SFL is that of foregrounding the paradigmatic axis of choice in the use of language when most standard grammatical frameworks would foreground the syntagmatic axis. The foregrounding of the paradigmatic axis allows for the analysis of a more comprehensive spectrum of language functions found within the language system, where actors, circumstance and processes can be specifically identified by cross analysing both paradigmatic and syntagmatic axes of lexical use and construct.

In order to study Intent in the CR PSS, the PSS is viewed mainly as dialogic occurrences between actors within the PSS such as producer, integrator, customer and end-user. The CR PSS whilst can at any instantaneous moment be described as having a set of elements that constitute a PSS, in general, a PSS is a living and evolving

phenomenon that consists of processes, of flows of events and activities. Since processes are actor driven, Intent of action, of desirability could be seen as an underlying current of motivation for processes, whether ideological or material. A dimension of the multifunctional constructs of the clause is to convey and construe the processes of reality in various contexts. This is done simultaneously by three metafunctional lines of meaning that include the textual, interpersonal and experiential:

1. The *textual metafunction* presents in the broadest sense, the theme and rheme of the clause. It pertains to the overall message concerned and manages the flow/coherence of the discourse.
2. The *interpersonal metafunction* presents the clause as proposition, whose meaning is interpreted consultatively with others. As such, clauses allow for interpersonal interaction, usually indicated in mood (subject + finite), modality (modal adjuncts) and polarity (positive/negative) constructs in discourse.
3. The *experiential metafunction* presents how reality is experienced and interpreted. It conveys the quantum of change in the flow of events as a figure (actor/sensor/sayer) in relation to a configuration of processes (material, behavioural, mental, verbal, relational, existential) set in a certain context that unfolds over time.

The three metafunctions provide a broad outline of meaning that occurs in discourse simultaneously manifest in the Transitivity system of language in use. It is the study of processes that constitute the system of Transitivity analysis (Halliday & Matthiessen, 2014), adopted here for the purposes of studying Intent in the CR PSS. Intent can be observed in the form of 'outer' and 'inner' processes. Outer and inner processes is most often cognitively perceived as intertwining, our experiences seem to fold unto each other as a single activity process through linear Time. What we experience as 'out there' often is related to how we feel 'inside'. Transitivity analysis in SFL however, through material process clauses (that of doing) and mental process clauses (that of sensing) has the capacity as tool, to disambiguate these intertwining processes as experienced through Time. Relational processes clauses that help identify and classify actors in contextual circumstances might also help

distinguish outer and inner experiences that in this study help uncover Intent as an underlying element in a CR PSS.

The framework of Transitivity analysis in SFL is based on the London School tradition, developed by M.A.K. Halliday during the 1960s. Halliday's work is built on J.R. Firth's works on linguistics (Firth, 1957). SFL is a framework that reflects how the architecture of language can be used as an instrument of systematic analysis of meaning making in context (Halliday & Matthiessen, 2014; Halliday & Hasan, 1985; Halliday, 1978; Halliday & Hasan, 1976; Firth, 1957). There are two ways in which Intent in a PSS can be studied via textual analysis from the empirical data retrieved. The first is to view focus on the text as an object of study in itself. In this instance, the text is studied for its meaning, why and how does it mean to readers. It answers the question, why would the text be valuable when studied in this context? The second way to study Intent in a PSS would be to focus on the text as an instrument of design, and what an analysis of Intent can uncover about the motivation in developing the PSS as a whole.

In the case of a collaborative robot PSS for example, the producers (usually engineers) might often collaborate with customers (or future users of the product) in order to propose a CR solution. In this case, all design ideas and formulations are captured in dialogue/text between the producer and customer. So the language system (meta-linguistic properties in lexicogrammar) in this case becomes an instrument of product-service design in its facilitating and moulding capacity. The two ways of studying Intent in a PSS are interrelated.

#### *II.4.1. Transitivity analysis: Type of Sensing, mental processes and Intent*

SFL can be seen as a linguistic toolbox containing various tools for specific purposes. In this study, the system of 'Type of Sensing' is used as analysis tool in order to uncover Intent in the CR PSS. Type of Sensing is usually conveyed through mental clauses in language, treated in grammatical analysis as four distinct types: *perceptive*, *cognitive*, *desirative* and *emotive*. Identified through verbs in mental clause constructs, the four types differ with respect to phenomenality, directionality, gradability, potentiality and ability to serve as metaphors of

modality. This specific tool is chosen because CRs have been designed to be specifically human-friendly and human work environment oriented. As a product, it seems to appeal to the human senses, some CR products such as Baxter by Rethink Robotics has a tablet that reflects eye expressions so that the robot can communicate its current state towards the user. A short example of Type of Sensing and Intent, illustrated in the use of mental clause constructs is shown in Text Example 1 (in underline).

#### *II.4.2. Transitivity analysis:*

##### *Material processes, processes of doing*

The study of Type of Sensing and Intent as most often indicated by the use of mental processes in clause constructs is complemented by a study of material processes or processes of doing / happening. Material clauses construe events as a flow of quantum change, taking place by initiation of input from a source of energy. In the case of a CR PSS, this source of energy could be human or robot, the latter due to that human users of CRs tend to personify robots and give them agency of their own.

The following text example from a transcript in the corpus data to this study is a short example of material clauses. The text example appears in the manner of MSO GTS version 6.4 (Nivre *et al.*, 2004). Although material clauses (in italics) are predominant, mental clauses (in underline) that express desire or Intent are also shown. In some clauses, mental and material processes follow each other (Text Example 1, line 1).

Text Example 1. Excerpt from transcript “220150624 Universal Robots Tegra Medical”

\$HB: now what we were hoping to find as a platform / that we *were scalable* / something that we *could take* internally that we *could do* all the engineering on the integration by ourselves without an outside resource or integrator / the collaborative class series robots have just come out when we started looking into it / and uhm / we really thought that was something beneficial because a lot of our operations we wanted to put together in mini cells and it's confined work spaces but operators *have* to be able *to interface* with the automation / so having big cages if it was a regular industrial robot would have / uh / wouldn't have been advantageous to what we *were trying to do*.

### *II.4.3. Perspectives of Agents and Actors in a collaborative robot product-service system*

Mental transitivity processes that help uncover Type of Sensing and Intent, and the manifestation of Intent in concrete material processes (processes of doing/happening) have agency and actors behind them. In Text Example 1, it is often “we” as agents in mental and material clauses. The “we” from Text Example 1 comes from a firm level perspective, a customer and end-user perspective to a collaborative robot produced by the Danish company, Universal Robots.

Agency and Actorship in the SFL framework can be studied in a systematic way through the Pronoun system of language in use. Most languages of the world have deictic words or directional pointer words that help interlocutors orientate their focus and perspective, illustrated in the use of “I/You”, “We/They”, “It” and “Its”. Having a deeper understanding of the actors behind the mental and material processes will help lend insight into the developmental or evolutionary trajectory of the CR PSS in general.

## III. FINDINGS AND DISCUSSION

SFL’s transitivity analysis, exploring Type of Sensing is a means of exploring Intent and the Agency/Actorship behind the Intent. The following sections will help illustrate how Type of Sensing and Intent can be uncovered using Transitivity analysis. The analysis is an illustration in answer to the first research question posed for this study:

- How can Intent, currently reflected implicitly in the tripartite characterisation of a PSS be made explicit in illustration as a core element of coherence in a PSS?

The concordance software was used as the initial means to manage the corpus data created for the purposes of studying a CR PSS. Not all features of the concordance software was used, and not all results will be discussed. Rather the feature most used from the concordance

software to the relevance of the study are the *word frequency list* that shows which words appear most in the discourse of a CR PSS, the *concordance plot*, which indicates which transcript/s can be used as most relevant examples for the word in context study and the *concordance* itself, that indicates Agency/Actorship behind the transitivity processes, Type of Sensing and Intent. This is useful in identifying which perspective tends to drive a CR PSS development. The examples that appear in the sections below are meant as illustrations, and are not necessarily indicative of exhaustive results.

### III.1. CONCORDANCE ANALYSIS

The transcribed data rendered a corpus of 2569 word types with 18136 tokens. Apart from determiners (*the, a*), prepositions (*to, of, in*) and content words that surround the semantic web of “collaborative robots” such as *robot, we, with, robots, collaborative, our*, etc. that make the top 0.05% (top 130 word occurrences) of the corpus word frequency list, the most frequent word pertaining to Type of Sensing is the word “can”. The word “can” is a mental transitivity process indicating of the Type of Sensing that is *perceptive*. In terms of a CR PSS context, “can” is often used in relation to *potentiality* and *possibility* of innovation, of function, etc. grounded in context of use through Time.

The concordance plot analysis for the word “can” indicates which transcribed texts contain the most frequent use of the word in context. It indicates which texts could be further analysed and shown as text examples in this article for the uncovering of Intent when studying a CR PPS. For the case of the word “can”, the best text examples would be Hit Files 5 (File: 20160121 Universal Robots five unique selling points, 15 hits), 6 (File: 20160229 Universal Robots Prysm Australia, 11 hits), 11 (File: 20161019 KUKA talks HRC trends at IMTS 2016, 10 hits) and 1 (File 20150413 YuMi Intro ABB Robotics, 10 hits).

There are 95 concordance hits for the word “can” in the corpus. The concordance program shows mostly agency in the transitivity analysis when “can” is used in material processes (processes of doing). About 28% (27 of 95 hits) of the concordance hits indicate a generic “you” as main Actor or Agent of material action in the processes.

The Actor or Agency of action as a generic “you” is indicative of the Type of Sensing and Intent that runs through the cline of the CR PSS.

Whether viewed from the perspective of pure product (product orientation in design and production to use and then service orientation), where “can” also indicates potentiality of material processes to be carried out such as “*you can program the robot*”, “*you can work right next to them*”, “*you can grab the arm*”, etc., it seems CRs as a product are designed, manufactured and programmed (where programming a CR is both user and service orientated in a PSS) to be producer-independent and more user-controlled for mid to long term use.

Other than material processes, the word “can” also occurs in relational processes. The use of the modal + verb “*can be*” in relational constructs point towards existential potential. Upon closer analysis of the collocates of “*can be*” that makes up 20% (19 of 95 hits) of the corpus results, shows that many examples are used in context of material processes or processes of doing, thus putting a heavy emphasis on how CR as a product continues to be purposed for user and service orientation. Some examples of clause constructs include, “collaborative robots *can be* readily *equipped* with”, “larger moves *can be programmed*”, “robot *can be installed adjusted* and *put into* production fast”, etc.

### III.2. TRANSITIVITY ANALYSIS

#### III.2.1. *Type of Sensing, mental processes and Intent*

Whilst few Type of Sensing words occur high up on the word frequency list of the corpus, following Halliday & Matthiessen (2014) framework of analysis for Type of Sensing, the mental process “want” was concordance searched using what is known as the wild card character, “\*” together with the root “wan”. The search term “wan\*” renders a string of search retrievals with variations of ending after *wan-* such as “*wanted*” and “*wanting*”. There is a total of 20 hits for the search term “wan\*”, with the word “want” (15 hits) occurring low on the word frequency list in the corpus, compared to the word “can” (95 hits). The word “want” is often used in context of a mental transitivity process, indicative of a *desirative* Type of Sensing and Intent. The other hits for the search term “wan\*” are for “*wanted*” (3 hits) and “*wanting*” (2 hits).

The concordance results for the search term “wan\*” uncovers the Agency / Actors in the transitivity process analysis, the main Agent and Actors of the mental processes being “we” that denote all perspectives

from producer, integrator and customer/user of a CR. Even when negative polarity “no/not” is used in collocation with the word to produce “*don’t want*”, the Agency and Actorship belongs to “we”, the examples being:

1. Customer/user perspective “we want to change it immediate and *don’t want* to wait till an engineer is coming over”
2. Customer/user perspective, “we *don’t want* it to be dependent on an integrator” and
3. Customer/user perspective, “we *don’t want* employees to feel that the robot is there to take their job away”

The Agency and Actorship that occurs with negative polarity in desirability reflects an inherent Intent of long-term viewership of product-processes. The aim is to become in the long run, autonomous from the manufacturer of the product in terms of being self-reliant on robot programming, the service orientation of which is seen as transferred from manufacturer to user of the product (reflected in examples (i) and (ii)). This long term view of independence, the development of autonomy from manufacturer and producer of product can be seen as an inherent strategy for sustainable business goals, keeping costs down in examples, and increasing in-house knowledge on management of new technology and technological processes. But sustainable business goals is illustrated not only in terms of user independence and development of own technological skills, it is also illustrated in terms of the Intent of developing an orientation towards human ergonomics, employee well-being and maximising human talent by taking away repetitive tasks (reflected in example (iii)).

The transitivity analysis findings for the search term “wan\*” illustrates that the fact that retrieved lexical items for “wan\*” occurs low on the word frequency list in the corpus does not in effect make it less interesting to study. Words such as “want”, “wanted” and “wanting” indicate desirative Intent in a CR PSS, where in this case, covers a range of long-term perspectivising (i.e. sustainability strategizing) of CR as a product, its use and its service orientation for future development of the product. In terms of the cline of product-service orientation, the mental process “want” suggests an evolving dialogic of a co-creative feedback loop from producer, to integrator and user/customer of the product.

The use of the high modal Type of Sensing “want” seems closely correlated to findings of the mental process high modality “need”. The corpus has 19 hits for the word “need” used in context. The majority of instances of “need” in the corpus pertains to the functional aspects of a CR from a customer/user perspective as a product. Examples of the word Type of Sensing “need” used in context include, “*need for safety*”, “*need to be flexible*”, “*need to be competitive*”, “*need to get high output*”. The use of the word “need” in the CR PSS context gives indication to the motivation of the design and manufacture of the CR as product, and how the product functions within its own eco-system, the CR PSS.

Another cognitive high modality word that indicates (strong) future expectations of what a CR PSS can deliver is contextualised in the use of the word “*will*”. “Will” occurs in low frequency through the corpus, with 32 hits in total. The results indicate that about 44% of the hits advocate main Agency and Actor for material processes used in combination with the high modal “will” to “the robot”, independent even of its producer or manufacturer. So once manufactured it is “the robot” that is seen by humans as the main enabler of activities in the workspace. This point of view is interesting because it uncovers a certain personification of a collaborative robot on the part of the human producers and users. The corpus findings seem to project the beginnings of an acceptance on the part of humans of a machine that humans can see as part of their eco-system. The high modal “will” also indicates a cognitive projection of perceived future expectation of a work scenario. 7 hits are followed by the relational verb “be” as example of perceived expected circumstance, such as “it *will be* the small part assembly application”, “yumi and humans *will be* working side by side” and “the robot *will be* even more useful”.

### III.2.2. Material process “to work”

While the transitivity analysis on Type of Sensing focuses primarily on mental processes, attribution of main Agency and Actorship in a CR PSS can help indicate its path of development or evolution. In looking at the highest occurring words in the corpus with regards to material transitivity processes, or processes of doing, the word “work” occurs at rank 52 of 2569 (top 0.02% of the list) word types, with

its verb form “to work” having 14 hits. The context of situation with regards to the material process of working highlights the collaborative aspect of a CR-human relationship, with the most common customer or user oriented collocates being “to work *with*” and “to work *alongside*”. The material process “to work” from product orientation in a CR PSS seems to emphasize safety features of a CR and ease of deployment of a CR, some examples being “*cageless, safe to work alongside humans*”, “collaborative robot *safe to work alongside humans*” and “*sawyer is safe to work with and easy to deploy*”.

### III.3. PERSPECTIVES OF AGENCY AND ACTORSHIP IN A COLLABORATIVE ROBOT PRODUCT-SERVICE SYSTEM

The inherent Intent and nature of a CR PSS as one designed to be collaborative and perceived as having future innovation potential, is predominantly illustrated in the corpus through the interpersonal and experiential metafunctions of language in use, reflected in the transitivity processes of Type of Sensing (mental processes) and doing (material processes). The transitivity analyses of various process types also indicate that the Agency and Actorship attributed within a CR PSS falls into the Pronoun system found in language of *I* (specific, 45 hits), *You* (generic, 108 hits), *We* (specific, 254 hits), *It* (product specific and system generic, 240 hits) and *Its* (product specific, 27 hits).

The Pronoun system in language in use, maps the various perspectives that reflect Type of Sensing and Intent within a CR PSS attributing Agency and Actorship (including personification of a robot as found in the corpus to this study) in various processes that occur in a CR PSS from manufacture of product to programming and deployment/use of product. These Pronoun system perspectives can be mapped in an all encompassing four quadrants, reflected in Figure 2.

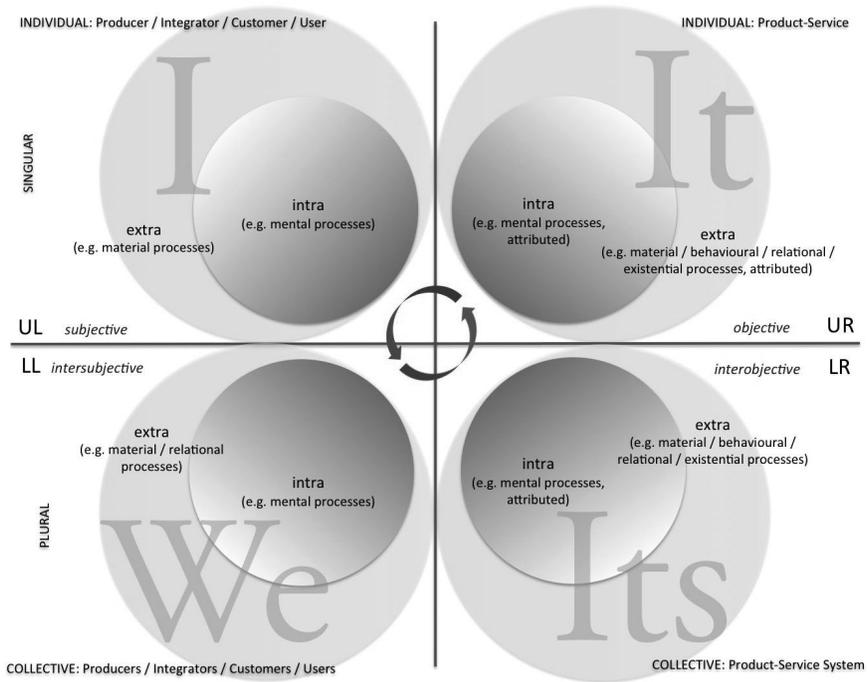


FIG. 2 – Agency and Actorship in a CR PSS mapped via the Pronoun system in language in use. The four quadrants show agency and actorship from intra/extra, singular subjective (“I”, “you” is implied), plural intersubjective (“We”, “you” is implied), singular objective (“It”) and plural interobjective (“Its”—systems view).

Because Type of Sensing and Intent are distinguished by different types of processes in the SFL framework, all Pronoun perspectives in their various forms, singular/plural, subjective/intersubjective, objective/interobjective, can encompass an “inner” and “outer” experience. These experiences whose meaning is reflected mostly in the interpersonal and experiential metafunctions of language is mapped through various transitivity processes, the inner experiences (intra) usually reflected by mental processes marked by verbs such as *think, like, want, wish*, etc., and the outer experiences (extra) usually reflected (though not exclusively) by material processes such as *to assemble, to work, to run, to pick and place*, etc.

In Figure 2, the Upper Left (UL) quadrant reflects the singular subjective perspective of “I”. This “I”, as with all other Pronoun perspectives

can reflect inner and outer experiences labelled as “intra” and “extra”. These experiences are usually indicated in various transitivity processes through the use of verb forms in language. The perspective and Agency/Actorship of “I” can come from any individual acting within a CR PSS, from producer, integrator (technician/engineer) to customer/user. Their Type of Sensing portrayed and Intent within a CR PSS will depend upon their function or role within the CR PSS and their immediate concerns regarding the task at hand.

The Lower Left (LL) quadrant reflects the plural intersubjective perspective of “We”. This perspective is collective and due to (usually) corporate culture or proximity of working with each other, the inner and outer experiences tend to be collectively shared, with allowance given for internal variation of these shared experiences. So, a producer of a CR as product, would and could in a CR PSS environment, collaborate with integrators as well as customers and users of the product in order to customise the product. These interpersonal and experiential metafunctions of “We”, intra-group or inter-group, are reflected through the various transitivity processes in language in use. The Type of Sensing and Intent as reflected in the UL and LL in a CR PSS most often materialises as a product-service that is reflected in the Upper Right (UR) and Lower Right (LR) quadrants. Just as one experiences reality as a fluidity of events and impressions between inner and outer experiences, the elements found in all four quadrants are interrelated. This is illustrated in Figure 2 at the centre of the four quadrants signalled by arrows drawn in circularity. The eco-context of the CR PSS provides the discursal space between the perspectives that provide for constant negotiation and re-negotiation of Type of Sensing and Intent. The perspectives reflected in the UR and LR quadrants are the singular object “It”, reflecting a specific product-service such as a CR in the CR PSS, and plural interobjective “Its”, reflecting the system of product-services. The perspective reflected in the LR of Figure 2 could be described as the broadest, reflecting a systems (intra-system and extra/inter-systems) view of a CR PSS. Perhaps a distinct feature in the CR PSS grounded mapping of Agency and Actorship as reflected from the data in the study’s corpus is robots as personified. This personification of a collaborative robot where a robot is attributed Type of Sensing and Intent would be reflected mostly in the singular objective “It”

perspective in the UR quadrant. As producers, integrators and users of a collaborative robot, humans project unto the machine, their own human interpretations and understanding of a robot's experiences in its purposed function and context. The identification of Type of Sensing and Intent from a personified robot is also uncovered by the types of transitivity processes associated with it in language in use.

#### III.4. INTEGRATING INTENT AND PERSPECTIVES OF AGENCY AND ACTORSHIP IN A COLLABORATIVE ROBOT PRODUCT-SERVICE SYSTEM WITH ARCHETYPAL PRODUCT-SERVICE SYSTEM MODELS

This section turns to address the second research question in this study:

- How can Intent in PSSs be used to complement current state-of-art understanding of its development processes?

Going back to the PSS literature on the conceptualisation of the PSS as conceived by Goedkoop *et al.* (1999) and in particular, Tukker's (2004) broader tripartite characterisation of (generic) PSSs from Pure Product to Pure Service, the Pronoun system perspectives that reveal Intent in a CR PSS can be placed alongside the conceptualisation of the PSS and its current applications in PSS research. The Agency and Actorship for the different types of PSSs, from (A) product-oriented, (B) use-oriented and (C) result-oriented PSSs are reflected in Figure 3.

From Pure Product to Pure Service  
*Intent* as uncovered by Transitivity analysis in a CR PSS

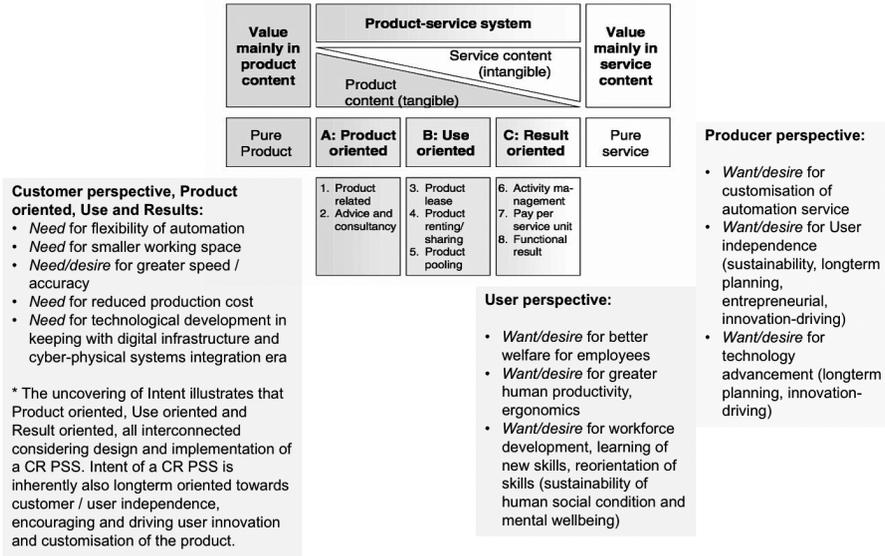


FIG. 3 – Placing the Pronoun system perspectives that reveal Intent in a collaborative robot product-service system alongside Tukker’s (2004:248) conceptualisation of a PSS.

Whilst the different orientation of PSSs A, B and C, produce variations in business models with eight archetypal resulting (Tukker, 2004), Figure 4 and its Pronoun system complements the (generic) PSS business models by uncovering Agency/Actorship behind the Intent for each type of PSS and its orientation. The examples of Intent for the various Pronoun perspectives is founded in a CR PSS, reflecting findings from the corpus data to this study.

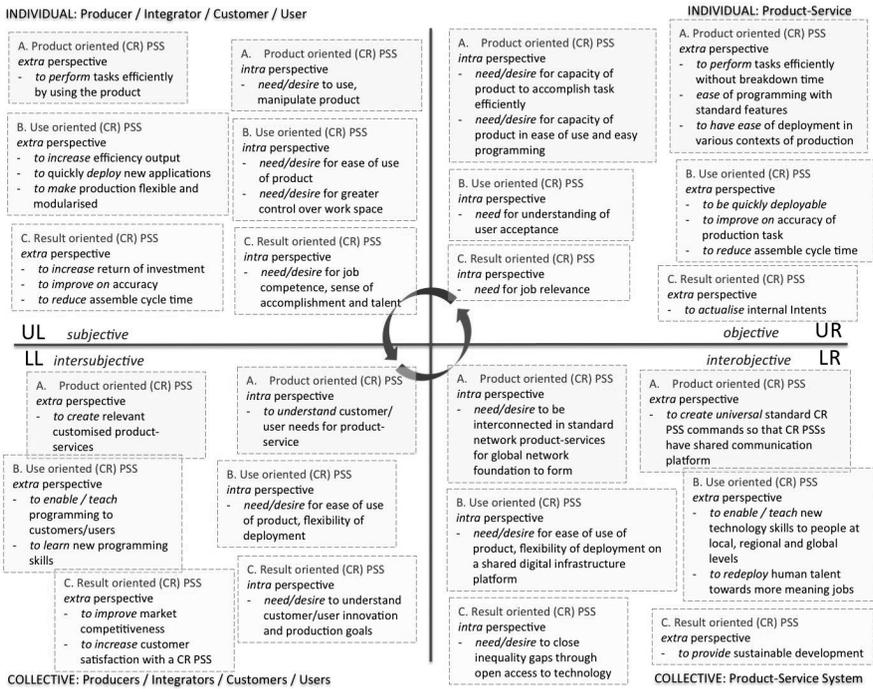


FIG. 4 – Integrating findings of Intent as mapped by the Pronoun system of language in use with Tukker’s (2004:248) conceptualisation of a PSS.

The elements illustrated in the four quadrants appear as examples of lines of inquiry, and are not meant to be exhaustive.

What can be seen in Figure 4 is that Type of Sensing and Intent, that have behind them, Agents and Actors, underlie all orientation types of PSSs from product to use and result. The underlying dialogic between agents of materialisation and actors, their interconnectivity in network and feedback is perhaps unique to the newly developing and evolving CR industry much due to the inherent nature of the product. The CR has features as a product that allows for it to be customisable, which means it needs technological expertise in programming and deployment to a specific work situation. This opens up a new field of service engineers known as integrators. Integrators can belong to various companies, the producer’s, the customer’s or end user’s or they may well be autonomous agents acting in their own enterprise. As such, the

characterisation of a CR PSS and its resulting business model is unlike the more traditional manufacturing enterprises that sell machines and then increasingly offer services. The CR is conceptualised and exists in its own eco-system of a CR PSS the moment it is ordered from the manufacturer. The manufacturer, together with the integrator might even do a scouting trip to the work area of the customer/end user in order to design a work cell where the CR can work together or alongside with a human operator. As such, the services offered in a CR PSS begins even before the product is delivered, the programming steps or assembly steps to the cell worked out and designed before product delivery. In the CR PSS business model, product-service is usually sold as one unit. What could then be considered is the use oriented business model, the discussion being whether the manufacturer will loan CRs and if so, on what basis, functions and for how long in a financial year or production cycle year.

### III.5. RESEARCH DESIGN AND METHODOLOGICAL APPLICATION

Apart from the complementing views of Agency/Actorship behind the Type of Sensing and Intent in a CR PSS that the Pronoun system can share with more generic characterisations of PSSs, the four-quadrant model has a further research design and methodology application in the study of PSSs.

Each quadrant lends a perspective that with consistent inquiry, would accumulate a body of knowledge that is specific to that perspective. As illustrated, a deeper understanding of the different business models of each PSS orientation type can be reached by designing research questions pertaining to that perspective. For the UL quadrant, phenomenological research studies pertaining to individual level actors of a PSS might lend insight into human talent management when implementing new technologies, or technology acceptance by individuals when introduced to new systems for example, can be designed. The LL quadrant has a strong sense for the collective “We” that includes most studies in PSSs with regards to how communication between actors (intra- or inter-firm level analysis) in a PSS might influence the development of current business models or business paradigm within the industry. There is a strong underlying aspect of culture and collective consciousness when

people interact with each other, so it is in this LL quadrant that many ethnomethodological and anthropological type studies can be adopted for PSS orientation study. Research inquiry pertaining to the UR quadrant could be examples of technological studies where engineering expertise is tested for a specific product-service function. For the CR as a product, it would be in this quadrant that knowledge about product capacity for accuracy in assembly and ease of programming can be empirically observed and tested with quantitative feedback. Predominant research methods employed for such studies situated in the UR quadrant include cognitive science for the study of CR behaviours and skills performance testing (human and CR behaviours for example). The UR quadrant within the field of engineering, bio-engineering and material sciences for example, would render most expertise and knowledge on CR as a product built in tandem with current digital, cyber-physical systems. Knowledge and research on the larger network systems view and system of systems view pertain to the LR quadrant. International policies for PSSs and in particular CR PSSs for example, could come under the LR quadrant. Current pursuance of industry standards and future factories where all machines are communicatively compatible and can operate across different platforms simultaneously are studies that could be placed within the LR quadrant arena of knowledge of PSSs. A detailed research design when considering all Pronoun system perspectives could help researchers map current knowledge of the field, and identify knowledge gaps in the field of inquiry. The Pronoun system model unfolds areas of knowledge reached and areas of knowledge to be acquired.

## CONCLUSION

This study has tried to address the observed fragmentation of theory and concepts in the field of PSSs studies. Taking the past decade's scholastic literature that indicates that the PSS has broadly been investigated from a tripartite perspective of product, use and result orientation, this study illustrates how an applied linguistics approach as qualitative method of study with regards to Type of Sensing and Intent can be used

as a cohesive element of study towards a more integral/holistic view in PSS theory and concept. The findings, founded in a more specific CR PSS, where the CR industry is young and fast developing, are meant to complement findings of current studies of other PSSs. The integrated findings are illustrated in Figure 4. An understanding of Intent, its actors and how the elements of the different perspectives interact with each other in a CR PSS can help researchers understand the directionality of development, or evolutionary path of a CR PSS.

From an industrial application perspective, the method use and results from the study of Intent in a CR PSS through transitivity analysis and Type of Sensing suggest that a CR PSS is indeed an eco-system of co-evolution between all actors in a CR PSS. For a CR PSS, a study of Intent shows that it becomes difficult to study any part of a CR PSS orientation (product, use or result oriented) in isolation. While studies on other PSSs can come from a pure product or pure service perspective (perhaps now more rare due to what a convergence in technologies allow in interconnectedness), in reality, even the cline of product-service orientation has been illustrated to be a constant negotiation loop of co-creation of product and service provided.

In address to the ongoing scholastic debate on defining the sustainability element of any PSS, perhaps what this study of Intent, taking a CR PSS as example, has revealed is that in PSSs, even if implicit, sustainability is an inherent element or awareness that is embedded in its processes. The questions that can then be addressed are not whether PSSs are sustainable but rather, in what manner can they continue to optimally evolve (be co-agently manufactured by producers, integrators and users/customers) within such an operating framework.

Scholastic research methodology perspective, the unfolding of the Pronoun system of perspectives potentially introduces new ways of seeing and studying a PSS. Each quadrant and zone of knowledge can be studied in detail, mapped for state-of-art as well as identified for knowledge gaps to be filled. The application of the four-quadrant Pronoun system model is not only relative in perspective, but relative to context of researcher intent and use. The limitation to this study is in effect the numerous other variables that constitute both the SFL framework of analysis and PSSs. SFL as an applied theory and framework of linguistic analysis consists of a rich set of tools for qualitative and

quantified qualitative text analysis. The combination of types of study for SFL applied method in understanding of PSSs is broad and might take a concerted effort of research interest to fulfil, for which SFL in itself represents a niche area of study even in the field of applied linguistics.

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