

PRODUCT WITH SERVICE, TECHNOLOGY WITH BUSINESS MODEL: EXPANDING ENGINEERING DESIGN

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ABSTRACT

Looking back over the last decade, the importance of an expanded understanding of engineering design has been shared within the engineering design community. Presented concepts and methods to support such expansion include Functional Product Development, Service Engineering, and Product/Service-Systems (PSS) design. This paper first explains PSS design as an expansion of engineering design, away from merely the physical product. Secondly, it gives a review of PSS research and a projection of future research issues, also ranging out into untraditional fields of research. Finally, it presents a new promising concept beyond PSS design; via an integrated development of technology and business model. This can be of particular interest for further research, especially due to its high freedom for designers and thus high potential for innovation.

Keywords: Product/Service-System (PSS), Innovation, Servicizing

1 INTRODUCTION

Manufacturers in developed countries today face severe competition with hardware manufacturerd in low-wage countries. This competition is expected to become tougher as the quality of products by manufacturers in developing countries is ever-increasing. Thus, firms in developed countries need to find ways to distinguish themselves in terms of value for their customers. As regards value, product quality is just one component. Service is also an important element to create value for customers. Manufacturers in developed countries indeed regard service activities as increasingly important today. Increasing amounts of manufacturing firms are strategically shifting from a “product seller” towards a “service provider” paradigm [1]. Importantly, service activity is increasingly incorporated into the design space, an area which has been traditionally dominated by physical products in manufacturing industries (see conventional theories for mechanical design; e.g. [2]). To do so, companies need to expand the object of engineering design from a physical product to an offering consisting of products and services, so that the whole design is effective and efficient. Such an offering is often called a Product/Service-System (PSS) [3, 4]. PSS design has many commonalities to user-centred design (UCD), as the key stakeholders are brought to a central position in the design process. However, it is important to understand that PSS goes further than UCD, as PSS design incorporates service as a key design parameter, which is not necessarily the case with UCD.

Looking back over the last decade, the importance of such an expansion has been shared within the engineering design community [5-10]. Different groups have presented concepts and methods to support such expansion, e.g. Functional Product Development [8]; Functional Sales [11]; Integrated Product Service Engineering (IPSE) [12]; and Service Engineering [13]. In common with these concepts, the target of design comprises combinations of hardware and support services. Taking stock of the research that has been carried out in this area over the past decade, one could ask, whether we have been doing the right things and in which direction should we head?

To share these concerns within the engineering design community and in an attempt to answer these questions, this paper first aims at giving a review of PSS research. Thereafter, it presents a new promising concept beyond PSS design; integrated development of technology and business model. The remainder of the paper is as follows. Section 2 first explains PSS design as an expansion of the engineering design paradigm, and reviews PSS research. Section 3 introduces the idea of integrated development of technology and business model. Section 4 presents a concluding discussion.

2 ENGINEERING DESIGN OF PSS

2.1 Conditions for PSS Design: Differences from Traditional Engineering Design

Blessing, Chakrabarti and Wallace [14] state that “the aim of engineering design is to support industry by developing knowledge, methods and tools which can improve the chances of producing a successful product”. In its generic nature, this statement provides a useful guide for engineers to consider their role and aims with design. However, this statement delimits itself to the domain of physical products, with services being excluded.

According to Tukker and Tischner [3] a PSS consists of “tangible products and services designed and combined to jointly fulfil specific customer needs”, also regarded as a value proposition, including its network and infrastructure. As a design research field, PSS is a new and emerging area, where the definition and study of ‘functional sales’ [15], ‘functional (total care) products’ [16], ‘servicizing’ [17] and ‘service engineering’ [6] all have contributed to the foundation and our current understanding of PSS as a phenomenon.

In the meantime, the latter half of the first decade of the new millennium has seen a particularly increasing interest in PSS design methodology, from a broader and more multi-disciplinary group of researchers, representing engineering, technology management and economical disciplines (e.g. [18-20]). Thus the PSS arena described here is still in its formative stages, where definitions, understandings and approaches to the field are still fluid. The design object that PSS represents can therefore be seen as expanding in a series of directions, when compared to traditional product design. The following paragraphs take an excursion into basic differences in conditions for a PSS design to be possible. Six basic conditions have been identified.

Conditions of competencies and disciplines

According to Tan & McAloone [21], the underlying strategic principle of PSS is to shift from business based on the value of exchange of product ownership and responsibility, to business based on the value of utility of the product and services. This implies a fundamental reassessment of core business, ownership, transactions, development and delivery of the ‘offering’ (this term is chosen so as to avoid confusion about the nature of a product or service), and client-customer relationships.

Thus the object of value for the providing company transforms from merely the physical artefact, to any chosen and targeted transaction between the customer and the providing company. Compared to traditional product development, a new set of competencies must be present in the PSS design activity, to enable the design, development and maintenance of a satisfactory relationship with the customer, who is in a closer (and often contractual) relationship with the providing company.

Conditions defining new design objects

PSS has until now been regarded as the joint development of product and service, plus the providing company’s subsequent delivery of services to the customer – when bundled together, dubbed “a system” [3]. Research in the field of PSS has so far established that the behaviour of services and products in the use phases of the product’s life are identical [22]. We therefore see the need to arrive at more usable descriptions and definitions of product, service and PSS, linking to an integrated understanding of customer-oriented value and utility, thus freeing ourselves of the somewhat artificial distinction of {PSS = product + service}.

McAloone and Andreasen [22] take a domain-oriented view of PSS, where a PSS offering is described in terms of an artefact domain; a time domain; and a value domain. This view is closely inspired by Ropohl’s system technical theory [23]. In each domain it is possible to describe the key distinctions and innovative developments that a company must undergo in order to create sustained value, customer lock-on and flexible solution-oriented business offerings to the customer.

New conditions regarding forms of production

The shift towards PSS for industrial companies can be described from many viewpoints, ranging from the desire to support a post-industrial society, the increased competition (and opportunity) to support an increasingly dematerialised world, to a necessary decoupling of competitive edge from cost, quality, time, etc. The current discussion of these reasons and observations of the augmentation of organisations’ interests in usability, use and service is pointing towards the definition of new production forms [24].

There are a number of approaches towards implementing and integrating new production forms into the organisation, that are highly relevant to successful PSS design. By broadening the perspective from product life cycle to customer activity cycle [25], we expand the design object for PSS. And by placing the customer in focus and understanding their needs for functional, efficiency-based and/or social fulfilment (this weighting differs, dependent on Business to Consumer or Business to Business), it is possible to develop a competence- and network-based approach to supporting the customer's whole activity – and not merely providing a physical good.

New conditions and opportunities regarding choice

As previously implied, PSS design should be based upon new degrees of freedom in the design process, due to a more broadly defined design object, closer contact with the end-user and an extended service period, compared with traditional business. But what should a PSS give the user, seen from their perspective?

Traditional mass-produced products (anything from software to vacuum cleaners) come with in-built and implicitly regulated properties, that the user must reconcile him/herself with, or find out how to work around, if the properties limit the intended use. A large opportunity of PSS, on the other hand, is that the user is present in the specification of use and usability, leading to the creation of choice, as opposed to living with in-built regulation.

Conditions regarding interventions or touch points

Tan and McAlone [21] adopt a morphological approach to understanding PSS types and characteristics, based upon observations of a series of cases. In this morphological approach it is interesting to observe the varying types of *interventions* or *touch points* (exchanges between provider and user, product and user, product and provider, etc.), describing which party is active or responsible for certain key activities and elements of the PSS.

We feel it important to think in terms of interventions, as this gives useful insight into the key activity dimensions of a PSS; areas which normally are *not* up for discussion when designing a traditional artefact. This viewpoint ought to give the PSS designer the insight into how active or passive the user is in each element of the PSS concept and in which situations to choose whether to delegate or to keep responsibility for the good, the information, the service, and so on.

Conditions regarding value perceptions

The engineering community has focused for many years on effective approaches for ensuring high value products and systems. The challenge here has been in matching the customer's judgement of value (subjective evaluation of goodness vs. investment incurred) with the company's own ability to provide products of high quality. The very nature of PSS design – where the relationship with the customer is designed to be longer and more intense; where focus is given to functional provision and not merely sales of artefacts; and where the product life view is matched with a customer activity view – gives many opportunities for the development task to come much closer to an understanding of value perception than in a traditional product development situation.

2.2 Nature of PSS Design

Having the conditions for PSS design in Section 2.1, this section describes the nature of PSS design. PSS design addresses the customers while the functions of physical products and providers' activities are media for satisfaction delivery. It should be noted that providers' activities, such as maintenance services, are included in the usage process. The evaluation by customers has a premium. Approaches to PSS design involve changes in the traditional design procedures, delivering processes, and engineering mindsets. Therefore, it has much influence on the provider.

Sakao et al. [26] argue that the following three dimensions are necessary to create space used to map various types of elements for PSS-design research; the *offer*, the *provider*, and the *customer/user* dimensions. It should be noted that the first one refers to both "product" and "service" elements of PSS. In addition, the other two, i.e. the provider and the receiver, are indispensable to address PSS.

The *offer dimension* addresses the elements and activities in the offering's life cycle. This includes the lives of physical products being a part of the PSS, as well as service activities. Successful design of PSS depends on a thorough understanding of the solution life cycle and active design of beneficial linkages with involved heterogeneous systems.

The *provider dimension* addresses the evolvement of the product/service providers' organisation and operations. This covers such issues as the setup of development projects, organisational streamlining of the company towards service delivery and the identification of necessary partnerships for the successful operation of services.

The *customer/user dimension* addresses the evolving needs of service receivers. It is crucial for the provider of services and products to be able to anticipate receivers' reactions to new offerings. In principle, any PSS design is supposed to address at least some aspect in all three of these dimensions, since service includes activities of customers and providers and products. As such, these three dimensions are fundamental for PSS design. In addition, anticipating and utilising the dynamics along each dimension is crucial. This implies that the essence of PSS design, especially if compared to traditional engineering design, lies in the utilisation of dynamics of and among the three dimensions of offer, provider, and customer. Figure 1 illustrates the linkages of some of the research topics to the three identified dimensions.

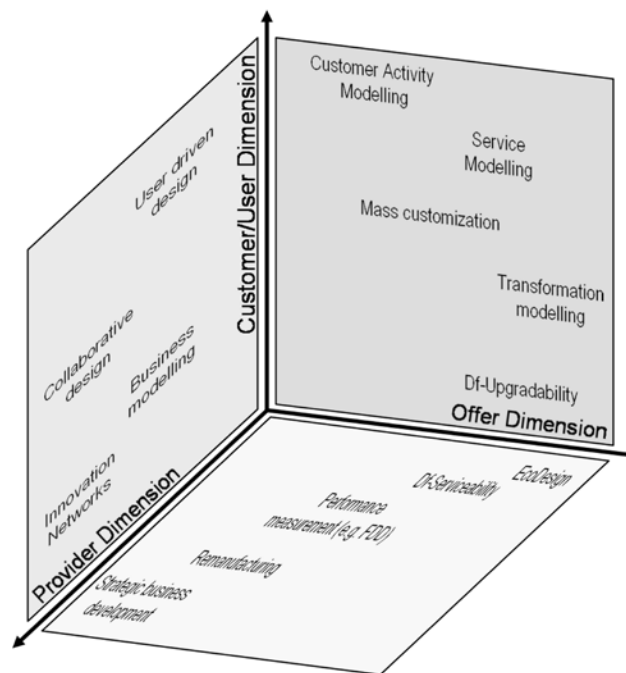


Figure 1. The three dimensions for PSS design [26].

In essence both products and services are just two modes in which companies attempt to deliver value to their customers. The 'product' versus 'service' discussion is not so much an issue of a new 'object' that has to be developed, but a new perspective on what kind of value is being created.

With PSS approaches we create a dependency between a (providing) company's operations and a (receiving) customer's activities. We have a close integration of operations, both tactically and strategically. PSS development models must inform us of the integration across the different levels of the company's development activities:

- ◆ Strategic business/product planning in cooperation with networks and service partners, i.e. development of PSS concepts.
- ◆ Product management and product development projects leading to new PSS 'offers', i.e. development of the product/service offer.
- ◆ PSS delivery system or function, which in steady relation to the customer delivers services, i.e. offer customisation and development of the service channel.

Fundamentally the difference in PSS in relation to traditional product development is that:

- ◆ the physical product is supported and enhanced throughout the customer's activities by the providing company (the business relationship with the customer may spread over several product upgrades and generations).

- ◆ the value creation is in the resulting activity where both the physical product, supporting services and the customer all play a vital role (the perception of value is beyond the physical product itself).
- ◆ the customer's activities are part of the value creation process and the providing company must interact closely with the customer throughout the life phases.

2.3 Existing Research on PSS

Researchers in the EU-funded SUSPRONET project [3] have contributed a great deal to the PSS research. From the perspective of engineering design, their contributions come mainly from an analytical-, as opposed to a synthesis/design viewpoint. For instance, the exhibition of *the product-service continuum* (from product-oriented, use-oriented, to result-oriented service) should be seen as an aid to *classification* as a part of the analytical phase of design (see Table 1). In addition, the work reported in [27] is exactly the result of *analysis*. Other literature such as Mont et al. [28] comes also from analytical viewpoint. This means that insight from this group of PSS research is limited to understanding the purpose of designing offerings, as opposed to methodology towards actually designing these.

Relatively recently, a group of research on PSS focusing on design has emerged. According to Sakao et al. [26], here we use the classification of the research targets into “PSS offer modelling”, “PSS development process”, and “PSS potential”. The first two, i.e. offer modelling and development process, have been basic targets of engineering design research as presented by Finger and Dixon [29] and [30]. Table 1 illustrates the targets of the reviewed literature that were taken from international journals.

Table 1. Classification of PSS design literature (journal articles) into the three targets

Research target	2008 and before	2009 and onwards
<i>PSS offer modelling</i>	[13] [31] [32] [33] [16]	[34, 35] [36] [37] [38] [39] [40]
<i>PSS development process</i>	[41] [42] [31] [43]	[44] [37] [38] [45] [46] [47] [48]
<i>PSS potential</i>	[49]	[50]

Note: Some articles appear only in one target in this table, which should be interpreted to be the main target of the articles, although they may address two or three.

In an attempt to create normative aids to PSS development, McAlloone et al. [22, 51] postulate that services and products are bound together by the use activity, that services are delivered or executed in a so-called ‘transformation system’ (TS), and that both products’ and services’ business aspects are based on value relations to the customer. The objective of this clarification is to allow the conceptualisation of new services to happen as a systematic pursuit of new solutions as it is known from engineering design. Based on a series of case studies and model-building endeavours with both industry and students, a series of interlinked PSS methodology proposals have been synthesised, supported by the domain insights into the technology, application area and necessary PSS competences.

Building on the above attempts, one can consider the expansion in nature of the PSS in relation to a product. By adopting whole (or at least extended) life responsibility for a product – which is inevitable in a PSS situation – the design task changes its nature. If seen from a PSS perspective, a manufactured product’s destiny should be to be distributed, sold and domesticated, i.e. brought into the surroundings and context in which it is to serve for a period. In this situation we may focus upon the product itself, the man/machine interaction (learning, training, job-situation, working conditions etc.), the product’s utilisation process (its productivity, reliability, yield, availability etc.) and the occurrence of failure, (repair, upgrading etc.). By adopting this stance the question of *system fit* arises, i.e. how well the product works together with other system elements and how well it contributes to the overall optimisation.

The product will be able to serve the user for a period, known as the *product service period*. After this period many different situations may occur with the product, from: returning to the manufacturer; being upgraded: re-used by a new owner; and finally subjected either to a planned and controlled disposal – leading to recycling, or a primitive disposal. So the total product life period from raw material allocation to this disposal situation may also be seen as a sequence of activities, all caused or disposed for by the designer.

A further significant consequence of PSS design is that the time domain is expanded, both by prolonging the period of time that the producing company has an active interest in and control over the product and also by creating the need to consider multiple product lives, where the product (artefact) can be subject to numerous users over longer periods. The consideration of multiple life phases poses a new and challenging set of criteria for the product planning and development activity to pay attention to, including: an extended stakeholder gallery; increased product liability; closer contact to the end-user; the risk of cannibalisation of existing/future products and markets; and a new opportunity (or necessity) to consider the meaning of core business [51].

2.4 Future Research Issues

A recent white paper on “Industrial PSS” [52] describes “... in 10 years the following statements will be relevant: Result-oriented business models evolve as an industry standard. Complex development processes are simplified by automatic configuration by Plug ‘n’ Play of product and service modules. Service will be provided globally by service supply chains based on modularised service processes.” In order to realise this picture in ten years, there remains a lot to research about PSS design. Sakao et al. [26] further discuss future research needed in the PSS-design area: Design process, organisational structure, and mindset.

Design process

More research is needed for supporting companies in how they can be successful at integrated product and service development. Methods, tools, and procedures should support providers to develop services that are economically and environmentally beneficial and they need to be tested and validated in firms. Several concepts and suggestions (e.g. [34] and [10]) should be fed back for research; now we need the empirical testing.

Organisational structure

The organisational structure needs to shift in a company. How to organise the company in order to match the organisational arrangements according to the services offered is one area, where more research can be performed. Part of this is the competence profile of the company that needs to shift when moving into services (e.g. more service technicians or more business and service developers could be needed). A logistics system and a remanufacturing system may also need to be developed.

Mindset

Companies undergo major changes in mindset. Companies that have a strong culture and pride in their products must also build up a trust and belief in their services among their employees. Services also need to have a high status and be incorporated into the company. The importance of the mindset and how that can build, in line with new company values, will be an interesting research area.

3 INTEGRATED DEVELOPMENT OF TECHNOLOGY AND BUSINESS MODEL

3.1 Implication from Theoretical Reasoning

What would be an interesting issue if engineering design were expanded to PSS design and further beyond? What could be addressed in order to make a bigger impact or to be more fundamental? Ultimately, a technology adopted can be the most fundamental, in comparison to an employed system, physical product as a part of the system, and material used for the product in the hard, technical side. In other words from bottom up, a material is chosen based on the product, which depends on the system, assuming a given technology. Consider, for example, a hybrid personal motorcar, which adopts a new technology for its engine. This car performs far better than other cars designed differently with a traditional petrol-engine technology, in terms of green house gas emission. The point here is the increased performance by the new technology surpasses largely that by a certain “new design” such as a car with a new body.

Therefore, technology development would be an interesting issue to consider if engineering design were expanded and further developed. It has not been addressed as the focus of engineering design. This becomes more interesting if considering the principle; as discussed in Section 2.1, the earlier in the design process, the more freedom designers have. Technology development exists beforehand for the traditional engineering design to begin.

Having explored this further expansion above, let us now find what to learn from the achievement by PSS design. PS design addresses both ‘hard’ and ‘soft’ issues, while traditional product design deals with the physical product, including its materials. Having learnt that, it is interesting to ask what could

be targeted as a part in the soft side of design object to increase freedom furthermore? The business model, rather than the organisational structure of a firm and service activity provided within the scheme, might have the biggest impact.

The result of this theoretical reasoning is depicted by Fig. 2 and has been named the “V-shape in techno-business”. This allows the positioning of different disciplines. “Integrated development of technology and the business model” above PSS design has the highest impact. The length in the horizontal axis for each depicted area can be interpreted as the degree of freedom in design.

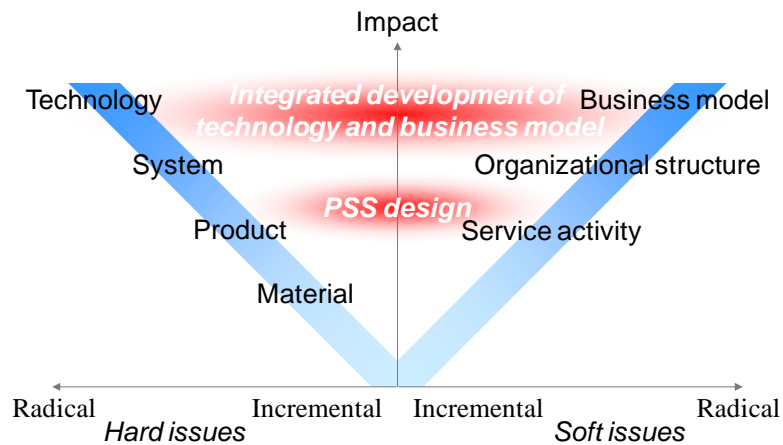


Figure 2. V-shaped relation in techno-business space (modified from [53]).

Longer time to market is characteristic of technology development (e.g. [54]) and has greater uncertainty compared to traditional product development. This poses a challenge to designers when expanding engineering design to include technology development. On the other hand, this is where services can be an effective way to decrease the impact of uncertainty. When a product with a new technology is launched, it could be combined effectively with a service as a package that takes care of technical risks.

Previous research has shown the business model to be an important factor in the PSS area (e.g. [28]). However, its integration with hard issues (i.e. product or technology) has not yet been discussed thoroughly. This is where the research need exists; in the integration of technology and business development. This integration is important, as they influence each other. For instance, a technology that was difficult or unfamiliar to users would require an intimate support service, which a provider would like to make money from.

Theoretical knowledge from the engineering perspective in this area is insufficient. Very little literature addresses this issue. For example, Efistathiades et al. [55] discuss an integrated process plan for implementing technologies, but do not focus on business models. This is no wonder, since developing such a theory of design/development aspects for PSS has just begun in the last decade. Indeed, utilising new technologies in developing PSS remains to be explored. However, this can be foreseen as a promising research issue following integration of products and services.

3.2 Industrial Needs

A driver for industry is pressure to decrease time-to-market generally. Emerging opportunities in the markets of developing countries is a particular driver. This is related to time-to-market, because current market opportunities may be lost without quick action. There is a need to implement new technologies for emerging markets, especially in the sector of environmental technologies. Developing countries, such as China, Russia and India, have a great need for solutions with environmental technologies to decrease their environmental impacts. In these situations, investigating alternative business models can be effective, because combining services in a different business model could decrease time-to-market. For instance, many Swedish firms have environmental technologies to potentially sell to the emerging markets, but building up a business model appropriate to the solution required is an issue [56].

3.3 Existing Knowledge and Research Opportunity

In previous research on integrated product development, Drejer highlights the need to integrate product and technology development that originates from the customers' requirement of shortened time to market [57]. Looking closely at technology development processes in the automotive sector, it is argued that technology development should happen before the requirement analysis for a product, because doing it the other way around takes more time and cost [58]. The technology developed is tuned after the requirement becomes available. An information processing model has been proposed to represent the process of developing products based on novel technical capabilities [59]. The process begins with exploration of the technological alternatives, and then moves to integration into a technological concept. Development of a detailed system and, then, production then occurs.

Drejer has argued for the need to integrate different disciplines, such as technology and sales [57]. Nyström demonstrates the need to address both marketing and R&D strategies within product development, and provided a framework for characterising and integrating marketing and technology strategies [60]. Another framework containing one line for business gates and another for technical decisions for a new product development process has been proposed, based on good practice in the chemical industry [61]. However, this framework does not address the design of a business model. Efstathiades et al. [55] discuss integrated process plans for implementing technologies, but do not focus on business models either.

Previous research in the PSS area has shown that the business model is an important factor (e.g. [28]). However, its integration with 'hard' issues (i.e. product or technology) has not yet been discussed thoroughly. This is where research is needed: the integration of technology and business development. This integration is important as they influence each other, for example, a technology difficult or unfamiliar to users requires an intimate support service, from which a provider would like to profit.

4 CONCLUDING DISCUSSION

By giving a review of PSS research in Section 2, we first highlighted some basic differences in conditions for a PSS design to be possible. This was followed by the nature of PSS design that the authors recognise. Finally, existing and future research was presented. To summarise our current insights, based on this exercise, we conclude with seven position statements:

- ◆ We believe that PSS development opens up for a greater arena of possibilities and therefore innovation practices than we have seen before.
- ◆ The engineering design object expands, implying that the product development task must handle more complex life cycle issues, multiple (and increased variance of) stakeholders, multiple product lives, societal issues, liability issues, etc.
- ◆ We have started to experiment and to attempt to develop a methodology for PSS development in the light of engineering design theory.
- ◆ We see the notional classification of the three elements: PSS offer modelling; PSS development process; and PSS potential, as a promising way to proceed with the support of PSS through an integrated approach.
- ◆ Considering the quantity and quality of the existing research on PSS design, there is a need to conduct the research further. Simply put, there are different types of elements of actions in PSS design that are not even well understood (see, for example, some recently initiated work, to understand more of PSS design [62]).
- ◆ We have presented a new promising concept beyond PSS design; integrated development of technology and business model.
- ◆ We are convinced that an integrated technology and business development model will shed great light on the task of PSS planning development and execution. However, little knowledge is available here also, and further research is demanded (an analysis of such a process can be studied in [63]).

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