Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 33 (2015) 64 – 69

www.elsevier.com/locate/procedia

Industrial Product Service System: A Case Study from the Agriculture Sector

Aiman Ziout[a], Ahmed Azab[a]*

Product Lifecycle Management Research Lab, University of Windsor, Windsor, N9B3S7,Canada

* Corresponding author. Tel.: 0015193005210;. *E-mail address:* Ziout@uwindsor.ca

Abstract

Recent research shows that manufacturers' contribution to sustainable development can be improved by adopting a product service system (PSS). It is argued in this paper that such non-traditional business strategy is a crucial decision to the enterprise. Metrics need to be identified at different levels: industry, enterprise, and product. The objective of this research is to identify PSS metrics for agriculture industry. PESTEL analysis is carried out to determine these metrics. A case study of a grain spreader is used to derive the appropriate metrics. Decision model is developed and its can be implemented by the PSS partners.

Selection and peer-review under responsibility of the International Scientific Committee of "9th CIRP ICME Conference"

Keywords: Decision making, Manufacturing, Product service system

1. Introduction

Product service system (PSS), and recently industrial product system, is a business model that promise a stronger customer-supplier relationship. Supplier can maintain long term relationships with customers by providing an integrated package of product and service. This integration is expected to increase customer satisfaction and facilitate supplier's ability to improve quality of their product due close exposure to customers and their needs. Adoption of PSS is motivated by sustainability-driven market and demand for less negative sustainability impacts [1] ; reduction in environmental impacts is a consequence of PSS, the case where supplier has more control on product operation during the use phase of product lifecycle. Resources conservation and optimization is default result of PSS. Manufacturers will be shifted towards designs that save them material and energy, such as design for long life product, design for reuse, design for remanufacture, and design for sustainability.

Challenges faced by a new product development are typically applicable to development of any new PSS [2]. Providing service with an existing or new product is associated with high level of complexity which is enough to be considered as equivalent to development of new product. Complexity associated with information flow, planning and decision taking is recognized by many researchers [3]. Information needed for generating knowledge about a market niche and potential customer for a PSS is one of major PSS challenges [4]. Educating customers about benefits and risks associated with PSS is a challenge needs to be tackled by the PSS supplier. Coordinating and planning PSS activities requires responsive and accurate decision, which involves processing of massive information. This challenge is addressed in this paper.

Cooperation between University of Windsor and a local company South Western Ontario, Canada representing the agriculture industry establishes the foundation for the research. Evaluation of PSS for agriculture machinery has been carried out with emphasis on addressing the challenges related to the handling of the huge amount of data and information regarding both the product and the market.

This paper builds on the findings of this partnership and proposed a switch to PSS. Metrics for evaluating the proposed PSS are researched, and an adaptive decision model is developed. Although the subject of the partnership is a specific product (Grain Spreader), the proposed metrics and decision model are meant to be applicable to evaluate and decide about PSS in the industry of supplying agricultural machinery.

Selection and peer-review under responsibility of the International Scientific Committee of "9th CIRP ICME Conference"
doi:10.1016/j.procir.2015.06.013

2. Problem background

Agriculture in southern Ontario, Canada is a hidden giant industry. Research team representing University of Windsor and local company operating and located in Chatham, Ontario, Canada establish a partnership to come up with innovative solution for a problem which grain storage industry is experiencing on a continuous basis. Harvested grains need to be stored in conditions that maintain high quality of stored grains. It has to be dried and aerated. In-bin drying is a common practice in agriculture industry. Heated air is injected from bin's bottom to top through stored grains. This process is called in-bin drying and used for wet grains to bring the moisture contents to quality standard. The success of in-bin drying depends on distribution of grains within the bin. Specifically, grains uniformity, and grains level. To achieve uniform and leveled grain distribution, grain spreader is used. According to our industrial partner's experience, current grain spreaders are not able to deliver the required quality standards, and they are not robust. Frequent maintenance and human intervention during operation is common among current spreaders.

Through initiative from the industrial partner, our research team is requested to develop an innovative solution for spreading and leveling grains intended for in-bin drying. Team has developed a methodology to gather information about product and its potential customers. A set of tools and methods are followed to gather the required information. The findings of this phase of the project led the research team to the proposal of PSS as a comprehensive solution for the researched problem. The proposed PSS is demonstrated in figure 1

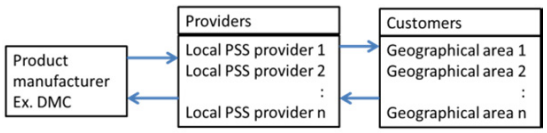

Figure1: Schematic diagram of the proposed PSS

Information prerequisites for this PSS are detailed in section three. The expected benefits for the PSS providers and customers are demonstrated in section four. Evaluation metrics are identified according to PESTEL analysis and shown in section five. Decision model is developed in section six to facilitate the decision making in the process of selecting PSS business model or traditional business model.

3. Information prerequisites for the proposed PSS

3.1. Product information

The data needed to properly define the product and correctly identify the related information is collected using the following data collection methods:

1. Field visit: the research team conducted field visits where the real life system is located. Pictures, videos, and measurements were documented. Also unstructured interviews were conducted with the industrial partner's employees.
2. Reverse engineering of existing competitive products: three major types of grain spreaders were obtained from the industrial partner. Their strengths and weakness are identified.
3. Grain spreaders users blogs: internet based blogs are carefully investigated; customers complaints, wishes, and requirements are distilled.

House of quality tool is used to visually present the information related to understanding the product functions, properties, and their interactions. Brainstorming sessions are conducted to determine the relevance of different important aspects of a good grain spreader. The following information is identified:

- Product functions
- Engineering features required to fulfill product functions
- Importance and contribution of each feature to the identified functions.
- The mutual effect between the identified engineering features.

3.2. Customer information

Information about potential customers for the proposed PSS is gathered through different means:

1. Industrial partner's sale department: geographical distribution of potential customers' locations is provided. This information answers the question about the ability of local PSS provider to fulfil the requirements of customer in his/her assigned area (see figure 1)
2. Website Research: A website is established to gather testimonials from farmers sharing their stories and experiences using various types of grain spreaders.

A detailed data collection is carried out in different forums. Relevant comments (either good or bad) are selected to help identifying customers' needs and wants. The collected data are analyzed based on strategic information model suggested by Rese, et.al [3]. The two categories of information are gathered:

A. Knowledge about the customer, which include:
   - The field the customer belongs to
   - Business processes performed by the customer
   - PSS complexity perceived by the customer
   - Main criteria for decision made by customer, e.g. cost, delivery, quality, etc.
   - Market to which customer sells the PSS

B. Knowledge about uncertainty and risk anticipated by the customer, which includes the following types of uncertainties:
   - Uncertainty about performance of the PSS
   - Uncertainty about technical consequences of shifting to PSS
   - Uncertainty about PSS provider responsiveness to changing customer's needs
   - Uncertainty about customer personnel's acceptance of PSS

4. Anticipated benefits of the proposed PSS

4.1. Anticipated benefits for customer

The customers of the proposed PSS are farmers and grain distributers; farmers harvest grains and my sore it at their farms or sell it to grain retailors who sore grains and resell it according to the demand over the year. By adopting the PSS, customers could anticipate the following:

- Benefit from the accumulated experience and knowledge of their local supplier [5]. Local supplier deals with many customers and get exposed to variants of their needs, wants, and problems; this exposure accumulate knowledge more than what a single customer can accumulate about the product and its performance.
- Obtain high quality and performance solution for their needs. The PSS is a package that provides end results which are guaranteed by the local provider.
- Eliminate or reduce risks which customers usually take through the owning and running the product.
- Reduce their personnel training requirements.
- Eliminate cost of product ownership [1]. Capital investment, maintenance, and running cost are eliminated. All these cost are included in the PSS.

4.2. Anticipated benefits for local provider

The local provider takes most of the risk associated with the PSS. Hence, more profit can be expected. Local provider plays a key role in the suggested PSS; the actual needs of the customers are transmitted to manufacturer through the local provider. On the other hand, the product and the service are delivered to the customer by the local driver. Due to this key role local provider can anticipate the following benefits:

- Gain more profit by providing service in addition to product. Competition can limit the product price and hence the profit margin, unlike the price of the service which is mainly determined by the local provider in the PSS.
- Establish sustainable and hard to break relationship with customers. This relationship is maintained by high customer satisfaction due to the expected high quality PSS.
- Expand the PSS portfolio to include more agricultural machinery. Proven record of success and established customer's trust make expansion more easily and less risky.

4.3. Anticipated benefits for manufacturer

The information which is gathered in previous section regarding product and customers shows that none of the current product manufacturer follows a PSS, Customers can by their grain spreader directly from manufacturer or local large farms who have experience in running grain spreaders (our industrial partner provide this service). Due to variation in customer needs, manufacturers had to produce variants of grain spreaders. A manufacturer who is willing to involve in PSS might gain the following advantages:

- Reduce number of produced variants; according to the proposed PSS (see section 7 for more details) one variant is capable of providing all customer needs, that is due to economy of scale which local PSS provider has over any individual customer.
- Generate extra profit by implementing end-of-life recovery strategy. The manufacturers may generate profit by taking back their grain spreaders at its end of life for the purpose of recovery. Recovery could include remanufacture or refurbishment of the product as a whole or reuse of parts and modules. Manufacturer can use the assessment model provided by [6] to assess the sustainability of this opportunity.
- Improve effectiveness of product development by integrating the customer in the process. Close relationship with customer through PSS provide effective feedback about the customer needs which can be effectively translated into technical features in a product.
- Improve effectiveness of continuous improvement process of the product as well as the service. Thanks to the continuous feedback from local providers who keeps the manufacturer updated with PSS performance and changes in customer's needs.

The benefits of the proposed PSS are not limited to the stakeholders mentioned above. Society at large and environment can also expect benefits. According to Tucker's principles of sustainability, sustainable society should not excessively extract materials from earth's crust nor increase the concentration of substances produced by society [7]. The suggested PSS with the option of taking back end-of-life spreaders satisfies these principles and hence contribute to sustainability of society.

Environment can benefit from the reduction in materials required to produce spreaders which are needed to fulfill customers' demands; potential reduction in product variants, reduction in number of units produced per unit of time, and long life product make up this reduction. Air pollution during product manufacturing phase is expected to be reduced due to the same reasons above. Energy consumption during the whole life cycle of the product is also expected to be reduced. But this reduction maybe outweighed by energy consumption during transportation of local provider from a farm to another; energy consumption need to be carefully assessed for the proposed PSS, otherwise the PSS will trapped in sub optimization.

5. Sustainability metrics of PSS in agricultural machinery

A shift from traditional business model to PSS model could be risky transition. Decision needs to be built on a comprehensive approach which considers all factors that affect the success of this transition. An approach that uses PESTEL analysis is followed to determine the metrics for PSS for agricultural machinery with a focus on the case of grain spreaders

5.1. PESTEL analysis

PESTEL analysis is a comprehensive approach developed by [8] for screening macro factors that affects the working environment of an organization. PESTEL stands for Political, Economical, Societal, Technical, Environmental and Legal aspects of an organization's work environment. It has been successfully used as comprehensive framework for studying firm's macro environment in different business sectors [8]. PESTEL analysis is done in two steps:

First step: relevant factors are selected from typical list of PESTEL factors provided by [8], brainstorming sessions, literature, and practical experience are used to identify factors which are relevant to PSS in agricultural machinery. Identified factors are listed in table 1

Table 1: Relevant PESTEL factors For PSS in agricultural machinery

PESTEL Aspect	PESTEL Factor
Political	1.1 Regional and global law
	1.2 National law
	1.3 Trade unions
	1.4 Taxation policies
	1.5 Vulnerable people
	1.6 Subsidizing firms
Economical	2.1 Interest rates
	2.2 Taxation
	2.3Insurances
	2.4 Economic competitiveness
	2.5 Labor cost
Societal	3.1 Attitude towards consumerism
	3.2 Attitude towards environmentalism
	3.3 Skills availability
Technical	4.1 Hardware
	4.2 Software
	4.3 Materials
	4.4 New developments
	4.5 New technologies
	4.6 New product
Environmental	5.1 Pollution and deforestation;
	5.2 Sustainability
	5.3 Recycling
	5.4 Waste disposal/ management
Legal	6.1 Local by-laws
	6.2 Health and safety legislation

Second step: relevant factors are detailed into sub factors, which make up the metrics for evaluating a PSS against traditional business model. Selection of these metrics was based on their existence in sustainability assessment literature, their contribution to PESTEL factors identified above, and relevance to the problem at hand (PSS of agricultural machinery)

Developing evaluation metrics that suit all stakeholders in the PSS is not easy task. Metrics that might be crucial for one stakeholder could be irrelevant to another. This fact is considered in developing metrics found in table 2; effort is made to select common metrics between all stakeholders. Metrics that do not apply equally to all stakeholders are dealt with through weighted score evaluation model (see details in section 7). Zero weight could be assigned to a metric to eliminate its effect in the evaluation model.

Table 2: Evaluation metrics for PSS in Agricultural machinery

Political metrics for PSS evaluation	
PSS Evaluation metric	**PESTEL Ref.**
1. Political stability	1.1, 1.2
2. Level of corruption	1.3, 1.5, 1.4
3. Subsidizing policy	1.6
Economical metrics for PSS evaluation	
PSS Evaluation metric [Ref.]	**PESTEL Ref.**
1. Manufacturing cost [9]	2.1, 2.2, 2.4, 2.5
2. Running cost[9]	2.1, 2.2, 2.5
3. Maintenance cost[9]	2.5
4. End-of-life cost[9]	2.4, 2.5
5. Property tax, insurance, and storage[9]	2.2, 2.3
6. Income tax[9]	2.2
Societal metrics for PSS evaluation	
PSS Evaluation metric [Ref.]	**PESTEL Ref.**
1. Net number of generated jobs [10]	3.3
2. Damage/benefit to human health [11]	3.1, 3.2
3. Green party pressure [11]	3.2
4. Equal chances for stakeholders [12]	3.1
Technical metrics for PSS evaluation	
PSS Evaluation metric [Ref.]	**PESTEL Ref.**
1. Technology/design cycle [13]	4.2,4.3
2. Product architecture, Level of complexity [13]	4.1, 4.2
3. Wear-out life [13]	4.1, 4.3
4. Standard or interchangeable item [13]	4.6
Environmental metrics for PSS evaluation	
PSS Evaluation metric [Ref.]	**PESTEL Ref.**
1. Use of material and energy [10]	5.1,5.2,5.3
2. Air emission [13]	5.1, 5.2, 5.4
3. Solid and liquid waste [13]	5.1, 5.2, 5.4
Legal metrics for PSS evaluation	
PSS Evaluation metric	**PESTEL Ref.**
1. Compliance to by-laws	6.1
2. Compliance to health and safety regulation	6.2

6. The logic of evaluation process

PESTEL analysis shows that not all factors are within the control of the decision maker in the PSS chain. Some political and legal factor could prevent establishing a PSS between the three major partners (manufacturer, local provider, and customers). This could happen when one of the partners is under political regime characterized by instability or partners belong to conflicting political regimes where this conflict affect the trade between them. Another similar situation arise when a compliance to a local by-laws or regulation make a complete or partial PSS infeasible. For example, Ontario's regulation prevent local provider between customers and manufacturer .in photovoltaic energy generation projects (customer has to be the sole owner of the project). If this is

the situation then, partial PSS that contains only two partners could be sought. Figure 2 demonstrate this logic.

In the case of agricultural machinery, the establishment of PSS depends on the customer; the assessment model provided in section seven can be used by the customer to decide on switching to PSS or keep the ownership of the machine. If customer favors PSS, then local provider need to make the decision wither to involve in a PSS or not. If local provider is willing to provide PSS then two scenarios arise; first a complete PSS can be established if the manufacturer is willing to be part of the PSS, second a partial PSS between local provider and customers can be establish if the manufacturer is not willing to be participate. These scenarios are summarized in figure 2.

7. Development of the decision model

7.1. Decision makers

The proposed PSS has three partners who might be the users of this model, they are:

- Customer who is the end user of the machine , usually framers or grain distributers
- Local providers: who buy machines and resell it to farmers and other end users.
- Manufacturer who produce the machine and its variants.

7.2. Decision variables

Decision variables for this model are the evaluation metrics shown in table 2. Decision maker needs to determine the value of each decision variable. Different scoring method can be used. Also weights can be assigned to each metric and/or to each PESTEL aspect

7.3. Decision alternatives

There are two alternatives for each one of the decision makers; either to keep the traditional business model or to switch to PSS.

Customer's alternatives:

1. Own the machine
2. Buy the service

Local provider Alternatives:

1. Buy and resell the machine to the customers
2. Buy and sell the service performed by the machine

Manufacturer's Alternatives

1. Make variants of the machine and sell to customers
2. Make one variant and sell to local providers through a complete PSS

Currently, manufacturers of agricultural machinery produce many variants of each machine type; so that they can satisfy wide range of customers' needs. PSS gives them opportunity to produce one variant that can be used by local providers to satisfy customers within their region.

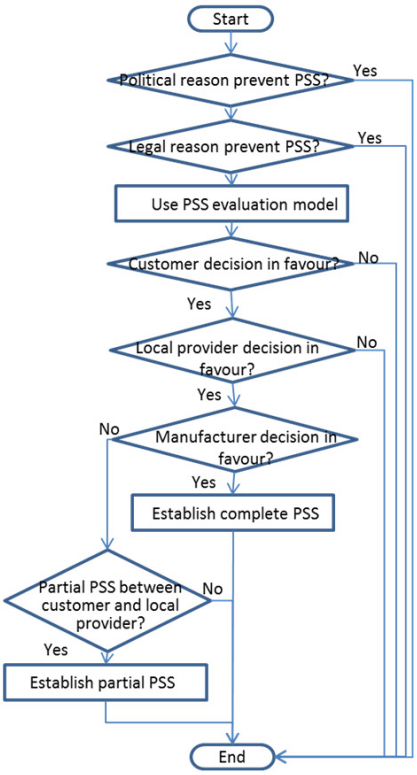

Figure 2: Logic flow of the evaluation process

8. Discussion and conclusions

Product service system is a promising business model for the agricultural machinery industry. It is beneficial to the economy, environment, and the society. Partners who are involved in PSS need to be aware of all metrics they could contribute to the success of this model. The identified metrics in this work with proposed decision model are considered as a foundation for informed decision about the sustainability of PSS in agricultural machinery.

PESTEL analysis is found useful as a tool to identify relevant metrics for the proposed PSS. Its comprehensiveness supports the confidence in the outcomes of the analysis. The field visits and interviews with industrial partners are found useful for the research team to fully capture the details of the problem as well as the big picture. This complete understanding led to the suggestion of a PSS in this field.

As an extension to this work, product design for PSS can be researched. The suggested alternatives for the manufacturer need to be supported by a new design paradigm, where design for long life, wear resistance, larger capacity, and ease of remanufacturing are considered and emphasized.

Acknowledgements

Authors would like to acknowledge the cooperation of the industrial partner for the information and their in-kind contribution, as well as NSERC Engage Program for for their financial support of the project.

References

[1] Thompson, A.W., Ny,H., Lindahl, P., Broman, G., Severinsson. M. (2010). Benefits of a Product Service System Approach for Long-life Products: The Case of Light Tubes. CIRP IPS2 Conference proceedings. Pp(83-89).

[2] Hoeffler, S., (2003). Measuring preferences for really new products. Journal of marketing research, 40:406-420.

[3] Rese, M., Strotmann, W., Gesing,J., Karger, M. (2010). How to educate customers about industrial product service systems –the role of providing information. CIRP IPS2 Conference proceedings. Pp(27-33).

[4] Kundu, S., A. McKay, P.G. Dawson. (2010). Understanding Information Requirements in Product-service Systems Design. CIRP IPS2 Conference proceedings. Pp(141-146).

[5] Rese, M., Gesing,J., (2013). What makes a PSS successful-An analysis of drivers. In Meier, M (Editor): Product service integration for solutions, Springer-Verlage, Berlin Hiedlberg, PP 287-298.

[6] Ziout, A., Azab, A., Atwan, M. (2014). A holistic approach for decision on selection of end-of-life products recovery options. Journal of cleaner production. Volume 65, Pages 497–516.

[7] Tukker, A.(2004). Eight types of product–service system: eight ways to sustainability. Experiences from SusProNet. Journal of Business Strategy and the Environment. 13, 246–260 Published online in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/bse.414.

[8] Carpenter, M.A, and Sanderse, W.G. (2009): Strategic management, a dynamic perspective, concepts and cases. Upper Saddle River, N.J. : Pearson/Prentice Hall, second edition.

[9] Kwak, M., and Kim, H., (2013). Economic and environmental impacts of product service lifetime: a life-cycle perspective. In Meier, H. (Editor): Product service integration for solutions, Springer-Verlage, Berlin Hiedlberg, PP177-189

[10] Schröter, M. Gandenberger, C. Biege, S. Buschak D.(2010). Assessment of the sustainability effects of product-service systems. CIRP IPS2 Conference proceedings. Pp(67-74).

[11] Ziout., A. (2013). Innovative design for active disassembly and sustainable product recovery. Ph.D. dissertation, University of Windsor, Windsor,Ontario, Canada.

[12] Kim, K.., Lee., D, Lim. C, Heo. H., Hong. Y, and Park,K., (2011). Development of an evaluation scheme for product-service systems. In Hesselbach, J., and Herrmann, C. (eds.), Functional Thinking for Value Creation. Springer-Verlag Berlin Heidelberg. DOI 10.1007/978-3-642-19689-8_45,

[13] Ziout, A., Ahmad Azab, Altarazi, S., ElMaraghy W.H.. (2013)"Multi-Criteria Decision Support for Sustainability Assessment of Manufacturing System Reuse" CIRP Journal of Manufacturing Science and Technology. Volume 6, Issue 1, Pages 59–69.