Promoting sustainable resource use through product service systems

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Abstract

In a world of declining prices for manufactured goods and increased global competition, many manufacturers have developed a range of services that complement and in certain instances replace traditional products, in an attempt to maintain or boost profitability. Resultant products have been classified as Product Service Systems (PSS) and comprise both an tangible artefact and intangible service, which are conflated through business processes to deliver value to customers. Research suggests that the environmental performance of PSS may be significantly better than that of traditional products. Theoretically, improvements in resource productivity that might be gained from use of PSS as opposed to traditional products are potentially enormous: somewhere between a factor of 10 and 20. To realise these environmental benefits, there is a need to identify instances where conventional material products can be substituted by PSS. This will depend on the criteria upon which consumers' decisions are made. One prominent theory of decision-making assumes that a decision to buy is based on the performance of product or service against well-defined criteria, such as price and quality. An analytical technique is required to enable consideration of multi-criteria and provide information regarding the relative importance of each criterion. A review of the literature was undertaken to identify suitable methodologies for this study. Three techniques were identified as being appropriate, namely: Choice Experiments (CE); Multi-Attribute Utility Theory (MAUT); and the Analytical Hierarchy Process (AHP). AHP was seen to be a suitable tool to enable consumers to compare product service systems with traditional products and identify substitutions, as it is a robust method that is particularly suited to decisions made with limited information.

Keywords: product service systems, multi criteria analysis, socio-economic

Introduction

In order to secure additional value from their traditional products, many manufacturers have developed a range of services that complement and in certain instances replace traditional products. For example: extended warrantees are complementary to white goods while voicemail is a substitute for answerphones. Such services can be described as Product Service Systems (PSS), they comprise a physical artefact and a tangible service that are combined through business processes to satisfy demand (Manzini 2003). For example, industrial washing machines are combined with collection and delivery services to provide a washing service to households. A taxonomy of PSS (White et al., 1999) has been developed within the literature to describe the variety of service approaches that have emerged, these include:

- *Product Orientated PSS* - ownership rights of the material artefact transfer to the customer and a service arrangement is provided to ensure the productivity of the artefact over a given period of time. Typical examples include extended warranties and maintenance contracts.
- *Use Orientated PSS* - ownership rights remain with the producer and the customer purchases use of the product over a given period of time. Rentals and leasing are typical arrangements distinguished by temporal contracts.
- *Result Orientated PSS* - the customer purchases an outcome. In contrast to the above, instead of leasing a washing machine, the customer pays for a quantity of their clothes to be cleaned and delivered through a washing service. Ownership of material artefacts are retained by the producer.

Crucially, firms' developing Result Orientated PSS gain an economic interest in increasing the durability and reliability of the physical artefacts that support PSS, since they will wish to minimise costs (variable and fixed) of service delivery. This incentive for firms' to reconfigure existing capital through service innovation to satisfy customer demands as they arise, diminishes the role that consumer durables play in satisfying demand. For example, a firm that currently produces answerphones may use their competencies to develop voicemail equipment, they would then have an interest in maximising the working life of their capital stock, rather than producing answerphones that are competitive in terms of price, but not necessarily durability.

Research suggests that the environmental performance of PSS may be significantly better than that of traditional products. For example, it is possible to conceive a situation in which instead of having a domestic washing machine in every home, a commercial laundry service uses a small number of durable industrial washing machines to satisfy the demand from many households for clean clothes. Such economies of scale may confer significant eco-efficiencies as far less material is needed to satisfy demand. Halme et al., (2005) identifies a number of ways in which PSS might offer superior environmental performance over traditional products:

- if the material artefact remains in the ownership of the producer, there is a financial incentive to produce more durable goods and the producer has responsibility for disposal;
- this approach increases intensity of use and the probability of a higher service yield before the product becomes obsolete; and

- producers use their competencies to ensure the optimal use of material artefacts, choosing the correct mix of services and the appropriate artefact.

Therefore, PSS have the capability to satisfy household demand more efficiently than traditional products. The improvements in resource productivity that might be gained from this alignment of environmental and economic objectives are potentially enormous: somewhere between a factor of 10 and 20 (Brezet, 1997). However, while some examples of PSS are emerging in certain markets, the environmental benefits of these are unlikely to arise automatically, since *inter alia* firms' will not be able to restructure their capital formation in the short term, rather investment in PSS will be made over the medium to long term (Mont, 2002; Cook et al, 2006). Ultimately the supply of PSS will depend not only on investment cycles but on consumer demand. Therefore, there is a need to determine whether consumers will substitute traditional products for these PSS and if not, what barriers prevent this.

Socio-economic appraisal of PSS

Identifying instances where conventional material products can be substituted by PSS, will depend on the criteria upon which consumers' decisions are made. One prominent theory of decision-making assumes that a decision to buy is based on the performance of product or service against well-defined criteria, such as price and quality. For instance, a consumer is likely to prefer goods that entail less expense and thus consume less of their disposable income. Therefore, it is necessary to:

- identify and validate the relevant criteria against which consumers make their decisions;
- construct a model that enables the criteria to be ranked in order of importance;
- demonstrate how decisions between products and services are made; and
- identify the conditions required for consumers to substitute between products and services.

An analytical technique was required that enabled consideration of multi-criteria and would provide information regarding the relative importance of each criterion. A review of the literature was undertaken to identify suitable methodologies. Three techniques were identified as being appropriate, namely:

- Choice Experiments (CE);
- Multi-Attribute Utility Theory (MAUT); and the
- Analytical Hierarchy Process (AHP)

CE is a stated preference technique, originally developed by mathematical psychologists for applications in market research. CE involves asking respondents to make choices between different consumption scenarios involving different levels of the criteria identified as important. Thus, CE questions force the respondents to 'trade off' performance of a good/service against several criteria, incorporating opportunity cost into the elicitation process (Farrar *et al*., 2000). Although CE would provide weights for each criterion and could provide a measure of how much consumers would be willing to pay for a PSS, the method is resource intensive and would have

entailed several hundred interviews with the general public in several regions. Because of this and also because CE is best suited to situations where respondents have a good idea of what they are valuing (many will not have encountered a PSS) this method was deemed inappropriate.

MAUT relies on the concept of utility, which is a measure of satisfaction or desirability (Holt, 1998), to provide the theoretical structure for representing the judgement of experts as mathematical functions (Brennan and Anthony, 2000). In MAUT studies, decision-makers apply a utility value to the relative importance of each criterion, then a total weighted utility score is defined for every criterion associated with a good or service; these scores are then summed to reflect the total utility associated with that good or service (Mussi, 1999). This technique is suitable for the evaluation of PSS, but is data intensive and requires the quantitative assessment of the performance of each alternative against each of the key criteria that will be identified. However, at present there is no evidence of how the PSS performs against key criteria, precluding the use of MAUT to evaluate PSS at this time.

The AHP (Saaty, 1980) has been shown to be a robust method of eliciting and using multi-criteria preference relationships in a range of applications. It is designed for situations in which ideas, feelings, and emotions are quantified based on subjective judgment to provide a numeric scale for prioritizing decision alternatives (Taha, 2003). The AHP is based on a matrix of pairwise comparisons between criteria, and it can be used to evaluate the relative performance of decision alternatives (for example products and services) with respect to the relevant criteria. AHP was seen to be a suitable tool for the purpose here, as it is a robust method that is particularly suited to decisions made with limited information.

The AHP method is designed to elucidate a preference scale for the criteria involved in a decision. The decision-maker is asked questions that compare criteria pairwise and asked to score them on a scale from 1 (equal importance) to 9 (extreme importance of one criterion). If there are n criteria, this results in an $n \times n$ matrix in which elements in opposite positions across the leading diagonal are reciprocals of one another. If the responses are fully consistent, the rows of the matrix are multiples of one another, there is a single non-zero eigenvalue (λ_{max}) equal to n, and the corresponding eigenvector, when normalised, contains the appropriate weights that rank the importance of each criterion. The columns of the matrix are multiples of this weight vector.

Responses will typically not be fully consistent, but Saaty (1980) has shown that, provided the consistency index, $(\lambda_{max} - n) / (n - 1)$, is below 0.1, the normalised principal eigenvector still provides a good estimate of a set of weights that capture the user's preferences. It has been found that it is possible to answer rationally and consistently and obtain a consistency ratio above 0.1 (Karpetrovic and Rosenbloom, 1999), the important issue is that respondents understand what they are doing and why the have scored as they have (Bodin and Gass, 2003). Discarding rational responses above the 0.1 limit can lead to a loss of valuable information. To this end some studies have used responses with a consistency ratio higher than 0.1 (Cho and Cho, In Press), up to 0.2, particularly with studies that have elicited responses from lay-people, paying attention that the respondents understand the scoring mechanisms (Wattage and Mardle, 2005). In this model, which elicits information from lay respondents, responses with a consistency index of up to 0.2 will be accepted.

This method can be applied to give a set of weights (α_{ij}) representing the importance of each attribute (*i*) for as judged by each consumer (*j*). The next step of the method is to rank the relative performance of the decision options (PSS or product) according to each attribute. If the preference for one good/service over another for criterion *i* is x_{ij}, the overall preference score for consumer *j* is y_j, where

$$y_j = \sum_i \alpha_{ij} x_{ij}$$

The value y_j is a measure of preference for one option over another.

Conclusions

In order to secure additional value from their traditional products, firms are becoming increasingly interested in Product Service Systems (PSS). In addition to providing opportunities for firms to maintain their competitive advantage, PSS also has potential to increase resource use efficiency. PSS may give rise, in theory at least, to dual benefits: increasing economic growth, and also decreasing the amount of waste to be disposed of. The uptake of these PSS will *inter alia* not necessarily coincide with business investment cycles, therefore, may not be attempted in the short term, but uptake will ultimately depend on demand for PSS. Therefore, there is a need to determine whether consumers will substitute traditional products for these PSS and if not, what barriers prevent this.

Consumer purchase decisions are often made by screening competing options against multiple criteria. Thus a Multi-Criteria Analysis model to rank the importance of key criteria and how traditional products and PSS perform against these criteria is needed. The results of this model may be used to inform policy decisions to ensure that the environmental benefits of the substitutions between PSS and traditional products are realised and that social and economic barriers to the uptake of this new service type are overcome.

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References

BODIN, L. and GASS, S.I. 2003. On teaching the analytic hierarchy process, *Computers and Operations Research*, **30**, 1487-1497

BRENNAN, P.B. and ANTHONY, M.K. 2000. Measuring nursing practice models using Multi-Attribute Utility Theory, *Research in Nursing and Health*, **23**, 372-382

BREZET, J. C. 1997. Dynamics of Eco-design Practice. *UNEP IE: Industry and Environment,* 20(1-2), 21-24.

CHO, Y.G. and CHO, K.T. In Press. A loss function approach to group preference aggregation in the AHP, *Computers & Operations Research*.

COOK, M. B., BHAMRA, T. A. and LEMON, M. 2006. The transfer and application of Product Service Systems: from academia to manufacturing firms, *Journal of Cleaner Production,* 14, 1455-1465.

FARRAR, S., RYAN, M., ROSS, D. and LUDBROOK, A. 2000. Using discrete choice modelling in priority setting: an application to clinical service developments, *Social science and medicine*, **50**, 63-75

HALME, M., HRAUDA, G., JASCH, C., KORTMAN, J., JONUSCHAT, H., SCHARP, M., VELTE, D. and TRINDADE, P., 2005. Sustainable consumer services. Business solutions for household markets. London: Earthscan.

HOLT, G.D. 1999. Which contractor selection methodology? *International journal of project management*, 16, 153-164

KARPETROVIC, S. and ROSENBLOOM, E.S. 1999. A quality control approach to consistency paradoxes in AHP. *European Journal of Operational Research* **119**, 704–718.

MANZINI, E. & VEZZOLI, C. 2003. A strategic design approach to develop sustainable product service systems: examples taken from the 'environmentally friendly innovation' Italian prize*. Journal of Cleaner Production*, 11(8): 851-857.

MONT, O. Clarifying the concept of product service system. Journal of Cleaner Production 2002; 10: 237-245.

MUSSI, S. 1999. Facilitating the use of multi-attribute utility theory in expert systems: an aid for identifying the right relative importance weights of attributes, *Expert systems*, **16**, 87-102

SAATY, TL. 1980. *The Analytic Hierarchy Process. Planning*, *Priority Setting*, *Resource Allocation*. McGraw- Hill: New York.

WATTAGE, P. and MARDLE, S. 2005. Stakeholder preferences towards conservation versus development for a wetland in Sri Lanka, *Journal of Environmental Management*, **77***, 122-132*

WHITE, A.L., STOUGHTON, M. and FENG, L., 1999. *Servicizing: the quiet transition to extended product responsibility.* Boston.