Operationalising and Managing Variety

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Abstract

To extend the conceptual model of a service system presented by Godsiff. (Godsiff, 2010). The model based on Ashby‟ s Law of Requisite Variety (1964) suggests a number of possible sources of variety including, the value proposition, the customer and producer inputs and the customer and producer outcomes. Frei proposes two strategies for managing variability, accommodation often provided by employees managing the variations presented by the customers and variety reduction through the value proposition. (Frei, 2006). This paper explores both the types of variability and the strategies adopted to manage variability through the analysis of a case study based on a commercial laundry.

Methodology/approach
Empirical research in single case study over 12 month period; data was collected through interviews with the owner manager and operational director, and twelve months operational and customer data was provided for analysis.

Key words
Service system, requisite variety, case, Viable System Model

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Purpose
To extend the conceptual model of a service system presented by Godsiff. (Godsiff, 2010). The model based on Ashby's Law of Requisite Variety (1964) suggests a number of possible sources of variety including, the value proposition, the customer and producer inputs and the customer and producer outcomes. Frei proposes two strategies for managing variability, accommodation often provided by employees managing the variations presented by the customers and variety reduction through the value proposition. (Frei, 2006). This paper explores both the types of variability and the strategies adopted to manage variability through the analysis of a case study based on a commercial laundry.

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Empirical research in single case study over 12 month period; data was collected through interviews with the owner manager and operational director, and twelve months operational and customer data was provided for analysis.

Findings
The commercial laundry has three broad customer groups, hospitality (restaurants and convention centres), hotels and hospitals. We considered each of the customer groups using Frei's (2006) framework of five types of variability,

1. Arrival variability: peaks and troughs in service demand.
2. Request variability: different requirements for each customer group.
3. Capability variability: customers with differing skill levels.
4. Effort variability: some services require customer input/ participation and customers will have differing willingness to make that effort.
5. Subjective preference variability: customers may have different and even contradictory views of what constitutes good service.

We observed that the scale of the variability varied considerably across customer groups although they were managed as a single organisation and through a single producer system. In addition we considered the strategies taken by the commercial laundry for managing variability and identified examples of accommodation and reduction in the same customer group. We also identified a third management strategy not proposed by Frei. This is based on differentiation and is similar to Beer's concept of amplification. (Beer, 1979)

Research implications
This research considers the differences in the five variability types for each customer group and relates that to the strategies adopted for managing variability. We extend the work of Frei (2006) to consider a third mitigation strategy based on amplification. (Beer, 1984)

Practical implications
We explore the managerial implications of taking an accommodation, matching and amplification strategy for the commercial laundry.

Originality/value
Many authors have developed a diagonal which matches levels of customer service to costs of production. This has many similarities with Ashby's law of requisite variety. This research begins to operationalise the constructs of customer variability and producer variety and to consider strategies through which organisations can match variety.

Key words
Service system, requisite variety, case, Viable System Model

Paper type
Research paper

1. Introduction

In this paper we examine the sources of variability or variety in a service system context and propose that Ashby's Law of Requisite Variety (RV) (Ashby, 1969) is a potential framework for understanding and analysing the interactions between customer and provider in a service environment. Variety is a concept frequently found in the management literature, however for Ashby it is a count of the number of states a system can be in rather than a concept. We expand on this to build more depth into "variety".

In section 2 we examine briefly the existing literature on the sources of variability in a service system, and discuss the potential for semantic confusion over the various terms employed, such as variability, variation and variety. In section 3 we discuss the difficulties inherent in testing systems and cybernetic theories like Ashby's, but find that empirical work and critical discussion has added to the depth and understanding of "variety". Building on this expansion we develop a new conceptual model with variety at its core in section 4. Section 5 tests this model against our case study: section 5.1 introduces the case study – a large commercial laundry; sections 5.2 and 5.3 use the new model to demonstrate how the laundry has responded to customer introduced disturbances; and in section 5.4 we discuss the implications for Operations Management. We summarise our findings and conclusions in section 6 and suggest areas for further research and development.

2. "Variability" in a service system

Kannan and Proenca identify the importance of variability: "in designing service systems one has to understand the sources and types of variability". (Kannan and Proenca, 2010) This is something this paper sets out to do. But before we begin we need to consider that (certainly in English) variability and variation and variety are words that are frequently used, sometimes interchangeably, for the same concepts, leading to potential confusion in the mind of the researcher and reader. As an example, we set out in appendix A dictionary definitions of the terms under discussion in this paper: from this can be seen the ease with which problems or misunderstandings can arise. For instance variable can be both a noun and an adjective; variation can be an act, process or condition; this leads in the literature to variation and variability often being used alternately or ambiguously. Having raised this note of caution we conclude that in the "noun" sense, most of these works mean essentially: a mix of, a number of, lots of, a wide range of. Bearing this in mind we will use in the following the words used by the original authors as far as possible.

Kannan and Proenca maintain that the service system needs to be "robust to these variations", and highlight the possible factors and areas they occur: operator and customer skill levels, perceptions of system complexity, preference and satisfaction, pointing out that variations are introduced by both the customer and the operator and the way they interact. They conclude that the emphasis of design of service systems should be more in customer facing functions, because both research and management effort in the past has "been to reduce customer contacts as much as possible during service operations as a way to improve efficiency." (Kannan and Proenca, 2010). This means that the service system should be seen as open rather than, as traditionally, closed.

There are a number of ways from a producer viewpoint that a systems design can react to customer introduced variability. Buzacott suggests that not allowing it (effectively closing the system) removes the need for worker task discretions (and thus removing producer introduced variability) and that simple jobs can then be allocated to a series flow line, while complex tasks are better suited to a parallel flow line (with one worker doing all the tasks). If customer introduced variability is to be allowed, this can either be dealt with by a employing a "menu", where the customer chooses from a specific defined set or a multi skilled worker analyses what needs to be done through some diagnostic activity. As more variability is allowed into the system more expertise and ability is needed by the producer to respond to and adequately deal with it. (Buzacott, 2000)

Frei (2006) suggests that instead of seeking always to reduce customer variability the producer should instead try to accommodate and match it, or while Kannan and Proenca (2010) suggest a potential for increasing it if this provides profitable opportunities. Frei proposes that 'throwing the customer into the works' introduces five types of variability

- request variability (different requirements for each customer);
- arrival variability (peaks and troughs in service demand);
- capability variability (customers have differing skill levels);
- effort variability (some services require customer input/ participation and customers will have differing willingness to make effort);
- subjective preference variability (different and contradictory views of what constitutes good service)

These researchers agree that a service system is constituted of customers and producers and their interactions.

We consider that a suitable model for analysing such interactions is Ashby's Law of Requisite Variety.   Ashby's RV is based on a simple model containing an external disturbance impacting on a regulated transformation leading to an outcome. For the outcome to remain successful the variety (defined as the range or number of actions) of the regulator must be equal to the variety of the disturbance. This leads to the dictum "only variety can absorb, or destroy, variety."(Ashby, 1964)

We suggest RV is an enlightening frame of analysis because it explicitly includes both aspects of the service system in the service encounter (customer and provider) and fits naturally with our definition of service based on a "significant presence of customer inputs" (Sampson and Froehle, 2006), which represent the disturbance. An analysis of the service interaction based on RV is given by Godsiff (2010), which states that there for continuing viability, the service needs to be on the line of requisite variety at which producer variety matches customer variety for any given value of customer variety. We now turn to consider empirical evidence for RV to determine what practical implications it possesses.

3. Empirical testing of RV

Ashbys RV is firmly in the tradition of systems thinking and cybernetics, and we find that the literature on testing cybernetic theories is not extensive. As Mesarovic et al. state there is a "gap between systems science and experimentation". (Mesarovic et al., 2004) This is reinforced by Geyer and Zouwen. Pointing out the success that cybernetics has had in producing innovative theory and methodology (eg modelling and simulation) they go on to identify the paucity of empirical research testing theory, recognising the challenges in designing this type of research. (Geyer and van der Zouwen, 1991)

The lack of empirical testing has been explored by van der Zouwen. He addresses the question of " what does the criterion of "empirical testability" mean in the social sciences?"   Empirical testing should result in propositions being refuted or confirmed, but the more complex the theory – the more interconnected in non linear and non-deterministic ways are the variables – the harder it becomes to form testable, and hence verifiable and falsifiable propositions. He suggests that there are two potential approaches to testability: the creation of complex simulation models (which then need to be tested against reality) or the formulation of simple bivariate hypotheses. (van der Zouwen, 1996)

Rosencranz and Fedderson echo this lack of empirical testing, suggesting difficulties around operationalising concepts and translating them into simple questions. (Rosenkranz and Feddersen, 2008). They themselves show how the Viable Systems Model (VSM) developed by Beer (1984), from Ashby's RV could be empirically tested using SEM but leave the test to later work.   In their study of VSM (which they note "has not been falsified in various applications and case studies"), they point out the serious challenge of establishing content and construct validity in the cybernetic field. Despite these significant inherent difficulties some researchers have attempted to operationalise Ashby's law.

Fransoo and Wiers use RV to examine whether how planners involved in scheduling operations resort to routine action when complexity increases (as predicted by behavioural science) or rather increase their variety of response instead. They use the hypothesis testing approach and existing ERP information as their basic data, rather than a survey. They find strong support for their hypothesis indicating that the planners (in their regulating role) are matching their variety with that of the input disturbance. They also introduce the concept of the frequency of occurrence of a particular state which we will adopt later in this paper. (Fransoo and Wiers, 2006)

De Raadt has published and tested variety extensively using the hypothesis approach based on surveys conducted within the insurance industry. (de Raadt, 1984, 1987, 1988). In his studies of modelling and then operationalising Ashby's law he suggests that successful outcome can be seen as not binary, but a ratio, implying that some regulation activity will be more successful than others, but that failure (unsuccessful outcome for a particular task) may increase non satisfactory outcomes but not lead to immediate non viability.   He also introduces the concept that the input states may be interlinked, which will lead to increased complexity in dealing with them. Using this and his ratio approach, he shows that the LRV will be skewed rightwards as complexity (measured by the degree of interconnected of states) increases, although it is unlikely, because of operational constraints, that the actual response achieved will match the response required. In a further study(de Raadt, 1989) he introduces further possible nuances to our understanding of the variety concept; firstly the importance of the spread of the states that are possible, and secondly that some states may be more important, or have a greater impact than others.

We suggest that neither hypothesis testing nor model building is the most appropriate research method for systems thinking and cybernetics.   Drawing on the realted field of systems biology, Mesarovic et al. suggest that understanding may be better obtained by searching for organising principles, rather than the construction of models describing exactly behaviour through space and time. (Mesarovic et al., 2004)

Accordingly, we will attempt to construct a descriptive model of variety to determine what are the implications for the organising principles of service systems design, building on the empirical and critical work done on exploring the many aspects of variety.

4. Developing the new model

In Ashbyian terms variety is a count not a concept. Variety is a count of the number of states a system can be in. From Weinberg and elsewhere a system is defined as a collection of things (within a real or implied boundary) which are more connected (for the analytical purpose of the entity drawing the boundary) with each other than with things outside the boundary. (Weinberg, 2001). The ""things" may for example be customer arrival times, or observations, or willingness/ ability of customers to participate in co-production. If all customers always arrive at the same time, the system of arrival times can only have one state.

The disturbance and the system comprising regulation, both possessing Ashbyian variety can be and most often are vectors. This means that the disturbance and the system's regulation have a number of different components by which it can be recognised and measured. Some may be more relevant at some times than others. For example, if we use Frei's (2006) framework in cases where co-production is not possible only arrival, request and subjective preference variability are present and in the case of a 'Big Issue' seller there is only customer arrival variability. RV suggests that the producer system needs to respond and match to all customer system components to remain viable and produce acceptable outcomes. In using the term variability Frei is attempting to frame the idea that the customer system could exhibit a range of states (ie be in a multitude of) in each of the components she considers relevant. They exhibit high variety.

By being a vector variety becomes a phenomenon of a complex system – a system of systems. Variety itself, is not a vector, it is a count; it is the disturbance and the regulator that have components, and hence variety (ie a number of states), that are vectors. Or more correctly, it is the nature and impact of (the many dimensions) of the disturbance, and the likely actions in response by the regulator that have variety (a number of different states) It should be noted that most empirical studies attempt to devectorise variety and only examine one component, for example request or response to that request.

At this point we suggest that "volume" is a "component", which itself can have a number of states; hence volume is not a synonym for the "inverse of variety". If all the customers always arrive at the same time, but vary significantly, in how many turn up per day, then there is low (one actually) variety in the "time of arrival" (when) component, but high variety in the "number of customers to be dealt with" component (how many); and if the producer is not matched in all these possible states in this dimension, generally a queue forms which may not be a satisfactory outcome for the customers at the rear of the line, and may lead to the supplier not remaining viable in the mid/long term

But as well as being a vector having components, which have variety (ie a number of states) there are elements or nuances of "variety" implicit and explicit in the literature that need to be considered and which may enhance our understanding of the variety concept. We have noted from some of the empirical testing that there are potentially issues which Ashby did not discuss in his initial analysis of RV which are relevant here: the probability of the disturbance or state occurring, the grouping of input states which might allow for one regulator response to cover more than one input state; if the disturbances are close then it is likely that the same response will be sufficient); (Dewhurst, 1991) ; the impact of that state, relative to other states; and the spread of states within each component . There are instances within OM literature where some of these nuances are debated: for instance we argue that the probability of the state occurring is best demonstrated by using Parnaby's "runners repeaters and strangers" analysis. (Parnaby, 1987). It is possible that each of these enhanced understandings of the variety concept have potential impacts already being explored within systems design.

We will call these identified issues or nuances “qualities” of variety. We have built a prototype model which shows the interplay between the components and qualities of the input disturbance, and the producer reaction. This is introduced below.

4. “Customer Disturbance Model”

This is a grid in which the “components” of the “customer disturbance” vector which we have derived i.e. volume, time of arrival, request, customer capability, willingness and subjective preference are analysed within each of the possible identified “qualities” of variety, i.e. number of different states, frequency of occurrence, spread of states, impact of each state, and real time of the disturbance, to develop a matrix in which the regulator / producer response can be analysed.

Table 1 Disturbance Model

"Variety"	Qualities	Variety as a count: how many different states can component be in	Real time – when does the disturbance occur	Frequency of occurrence of each state	Spread of states	Impact of each state
Components						
Volume						
Arrival time						
Requests made by/for customers						
Capability of customer to do						
Effort customer willing to exert						
Subjective preference for how delivered						

5. Illustrating the concept

We recognise the challenges in understanding the concepts introduced in this paper and have set out to provide a case study through which we can ground these ideas. Any organisation could provide the material from which to examine the disturbance model, however we sought a case which would provide

1. Excellent data access, in such an exploratory case we recognised that we would need to work closely with managers to refine our ideas and perhaps frequently return to the organisation to collect additional data.
2. A limited amount of variety, where the company would be operating in a stable environment for some time and where we could control for some of these components and qualities both in input and production and also have a limited range of outcomes.

All of this was necessary so that we could analyse something manageable through which we could illustrate our model.

5.1 Case study background

International Linen Service (ILS) is the second largest commercial laundry in Adelaide, South Australia, where there is a relatively mature industry. It has a turnover of some A$15m an EBITDA of 25% and employs around 140 FTE. It has been in operation for over 25 years. They have three major customer groups:

- Hotels have single and queen sheets, bath towels, pillowcases and hand towels.
- Hospitals have single sheets, pillow cases, towels PLUS a wide range of sterilised items e.g. surgical scrubs.
- Hospitality, restaurants and convention centres with napkins and tablecloths.

Twenty years ago the laundry washed customers' own linen. ILS collected and cleaned the linen and delivered it back to the customer. Since 1995 ILS has owned almost all (currently 97%) of the linen in the supply chain and leases the linen to the customer. The advantages to the customer are threefold:

- Convenience: the customer only has to collect up the linen and ILS will collect and take away the problem
- Cash: the customer can release all the capital tied up in linen. For some hotels this can be over A$100,000
- Cost: through the use of specialised equipment ILS can process linen much cheaper that it can be done in-house.

By owning all the linen ILS is able to pool some of the risks of demand variability between customers. ILS does this by limiting the type and colours of linen that they provide. For example, they provide white queen sized sheets to all hotels, white single sheets to hospitals and white standard sized tablecloths to restaurants. In this way ILS balances demand variations across locations although risk pooling across the three markets is more difficult.

The data was collected through a variety of research methods including eight interviews with the owner manager and operations director over a period of 24 months, we were provided with access to management information on customer demand and factory throughput. We also conducted three two-hour sessions observing the processes of initial sorting, washing and ironing through to storing. Finally, we were provided with access to some of the major customers and were able to observe the customer process of removing the linen from a hotel bed through to loading on the van.

5.2 Findings

The basic process is illustrated below in figure 2. The linen is used then moved to the laundry where it is washed, dried, ironed etc, re-packed and then transported back to the customer. When the linen is too warn to be washed again it is rejected and each month around 11% of all linen is replaced.

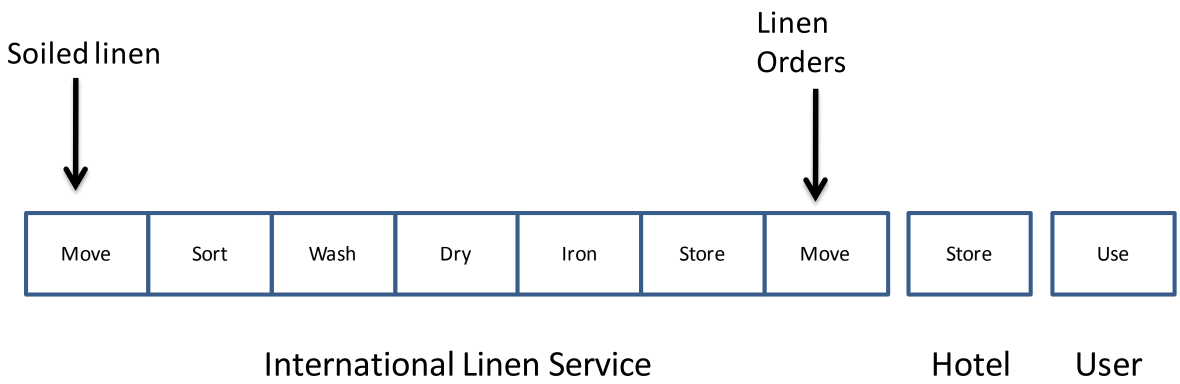

Figure 1 Basic Process Flow

We identified two different important disturbances. The first is the soiled linen the second is customer orders for new linen. These are to some extent decoupled in that there are storage places for dirty linen and also available storage in the warehouse where clean, that is processed, linen is stored. This analysis focuses solely on the processing of soiled linen.

In terms of the components of customer input variety we focus here on three; volume, arrival and request. In this process there is no co-production, ILS is the resource that carries out all the processing. The customer may do some sorting of the dirty laundry but has outsourced all the cleaning of the linen to ILS. We can therefore remove from our analysis capability and effort variety, although we recognise that including these might lead to a radical process re-design, however that as not the purpose of this investigation. We consider that customer willingness and ability are more relevant to service encounters where co-production is occurring. Subjective preference variety is included as the outcome of Ashby's model and will be considered in later analysis. We produced table 2 as a summary of our findings.

Table 2 Customer Disturbance Model for ILS

	Qualities				
Components	**Variety as a count: how many different states can dimension be in**	**Real time – (when does the disturbance occur)**	**Frequency of occurrence of each state**	**Spread of states**	**Impact of each state**
Arrival time (pick up from the customer)	There are theoretically an infinite number of states of arrival time. However, in practice ILS limit the	The arrival time for the pick up of dirty laundry occurs between 06.00 and 11.00. The arrival time	In practice the pick up vans arrive close to their schedules time 95% of the time.	This is not really a major issue as this is scheduled and arrives in a pre-determined pattern.	After midday this has a significant negative effect

	arrival times by picking up the linen from customers on a pre-determined schedule.	at the laundry is between 07.00 – 12.00.			
Requests made by/for customers	Laundry is either allowed (in the contract) or not allowed (Eg ILS do not do personal laundry)	Has no impact.	There are occasions when ineligible laundry is collected (only identified when the laundry bags are opened) but these occasions tend to be customer mistakes.	Low because it is either acceptable in the contract or not.	Very low – because of value proposition
Volume	High, between 63 and 111 tons.	Volume has no effect 'real time'. The issue of when each batch of dirty laundry arrives is covered in arrival time	Weekly volume follows an approximate normal distribution.	High - Over the busiest period of the year this varied between 63-111 tons	Yes, at extremes

5.3 Producer System

This section summarises the customer system disturbance using the three relevant components of variety and considers how the producer system responds.

Arrival variability (when)

Were the customer were to be responsible for delivering the laundry to ILS then there would potentially be very high variety, however because the linen is owned and the process managed by ILS the variety is small. This is primarily because this is managed through a daily schedule. Our interview data backed up by analysis of arrival times indicates that each customer has a set pickup time and that is set out in the contract schedule. The between customer inter-arrival variability is also small as all customers are on a scheduled route, except for a few very small customers. Should the customer have additional items of laundry that require picking up ILS has the ability to reroute its pickup vans. It is only in very exceptional circumstances that ILS will pick up laundry outside the scheduled times and these occasions are often to increase the amount of stock in the systems at times of shortage. The sorting process at ILS is a short and intensive session where staff load 50Kg containers with laundry sorted into categories (see below). Should arrival variability increase then staff have to staff longer to await the delayed delivery, however this is unusual and has a limited cost penalty. The implication of having very low arrival variability is that the number of staff required in the unloading and sorting area is relatively constant as there are not times of peak loading.

Request Variability (what)

Request variability is very limited. In the initial contract phase ILS limit the types of linen they will provide. Typically, these are white queen sheets and towels for hospitals, white tablecloths for restaurants and white single sheets for hospitals.

We assessed the response system for request variability using data collected during a two-week period in January 2010. January is a particularly busy period as it includes much of the laundry from the Christmas period. During this period the laundry processed 219 identifiably different items. Figure 2 is a snapshot of the items with their quantities and weights.

219 different items might seem a considerable amount of request variety but in practice there are approximately 16different categories of 50Kg containers. These are: aprons, sheets, tablecloths, miscellaneous laundry, pillowcases, blankets, miscellaneous prepack, dust mats, prepack bundles , incontinent items, robes, serviettes, tea towels and towelling. ILS differentiates between whites and colours for sheets and towels. So, in practice (because of the contract) the response system deals with 16 categories (sheets and towels are white/coloured) even though the customer will order from 219 different items. In practice the request variety is even more limited.

If an item is outside the agreed contract it is rejected and returned to the customer. A very few items are processed through a separate washing, drying operation which deals with a few, highly diverse items. This is completely separate from the main wash/dry operation.

Table 3 Item Types

3	Group	Code	Description	Qty	Kgs
4	SHEETS	SHEQ	Sheet Queen	32,036	36,521.04
5	SHEETS	SHES	Sheet Single	43,187	26,775.94
6	TOWELLING	TOWBL	Towel Bath Large	48,922	22,504.12
7	BLANKETS	D11	Blanket White	21,763	22,154.73
8	TOWELLING	TOWBXL	Towel Bath XL	22,410	13,446.00
9	SHEETS	SHEK	Sheet King	8,320	10,566.40
10	TOWELLING	TOWB	Towel Bath	20,861	8,761.62
11	PILLOW CASES	PC	Pillow Case	85,041	8,801.00
12	SHEETS	SHEDR	Sheet Draw	16,187	8,093.50
13	TOWELLING	TOWBC	Towel Bath Coloured	13,954	5,860.68
14	TOWELLING	TOWSB	Towel St Bath	10,010	5,575.57
15	TOWELLING	TOWBM	Towel Bath Mat	32,583	5,511.09
16	DOONA	CDQ	Cover Doona Queen (NOG)	9,515	7,891.71
17	SHEETS	SHET	Sheet,Trolley	6,574	4,075.88
18	DOONA	CDK	Cover Doona King (NOG)	3,730	6,126.20
19	BLANKETS	C31	Counterpane	16,876	5,896.93
20	INCONTINENT ITEM	TK39	I.B.S.	2,966	2,752.45
21	ROBES	ROBE	Robe	2,856	2,826.60
22	MISC PREPACK	C40	Gown Utility White	13,541	3,655.83
23	MISC PREPACK	C40A	Gown Utility (2 Shoulder)	6,442	4,457.99
24	TOWELLING	TOWH	Towel Hand	26,210	2,621.00
25	SHEETS	OVSHK	Oversheet King Patterned	2,039	2,589.53
26	TOWELLING	TOWFW	Towel Face Washer	90,712	2,267.80
27	TOWELLING	TOWSBM	Towel St Bath Mat	6,960	2,088.00
28	MISC LAUNDRY	MOP	Mop Heads	2,394	1,915.20
29	TEA TOWELS	CLGL	Cloth Glass	24,388	1,877.88
30	TEA TOWELS	CLTEA	Cloth Tea Towel	31,874	1,816.82
31	DOONA	CD	Cover Doona Not Out Goods	3,876	3,982.46
32	TEA TOWELS	C10	Duster	51,492	1,647.74

Figure 2 Item types

Volume Variability (how many)
This is the greatest cause of concern for ILS. Weekly volumes vary between 68 and 111 tons, a substantial variation of 63%. This obviously has implications for staffing numbers and ILS has had to adopt a policy of employing hourly paid staff and calling additional workers in on a short-term basis. This is not possible for all part of the process for example in the ironing section even though it is carried out using large machines it requires some skill in setting up this sheets to be ironed.

There are considerable fluctuations in demand for linen from customers even when hotels know their room bookings, anecdotal evidence suggest that they can get the volumes spectacularly wrong eg we were told of an example of a hotel that had over ordered to such an extent that it was holding 9 months stock. ILS are now trying to deal with customers' volume fluctuations by analysing their order patterns and smoothing these over a fixed period. They are also now placing customer representatives with the larger hospitals and hotels to do the ordering for the customer. However, by the nature of their businesses many of these customers do have considerable daily variations and this does need to be matched in ILS' response system.

5.4 Implications for management

Ashby's law suggests that the optimum point is the matching of response to disturbance. In Figure 3 we can see that positions A and B correspond to a matching of response and customer variety (on a log scale of 1, 2 some, lots). It is interesting to consider the implications of being off the line, for example position C (excess producer response) is a position of too much resource and therefore cost. Position D is a position of too little resource and the outcome is a non-viable system where the customer's expectation of outcome will not be met. There is of course a matching of response to disturbance for each of the different components of variety, which in this case is 3, volume, arrival and request.

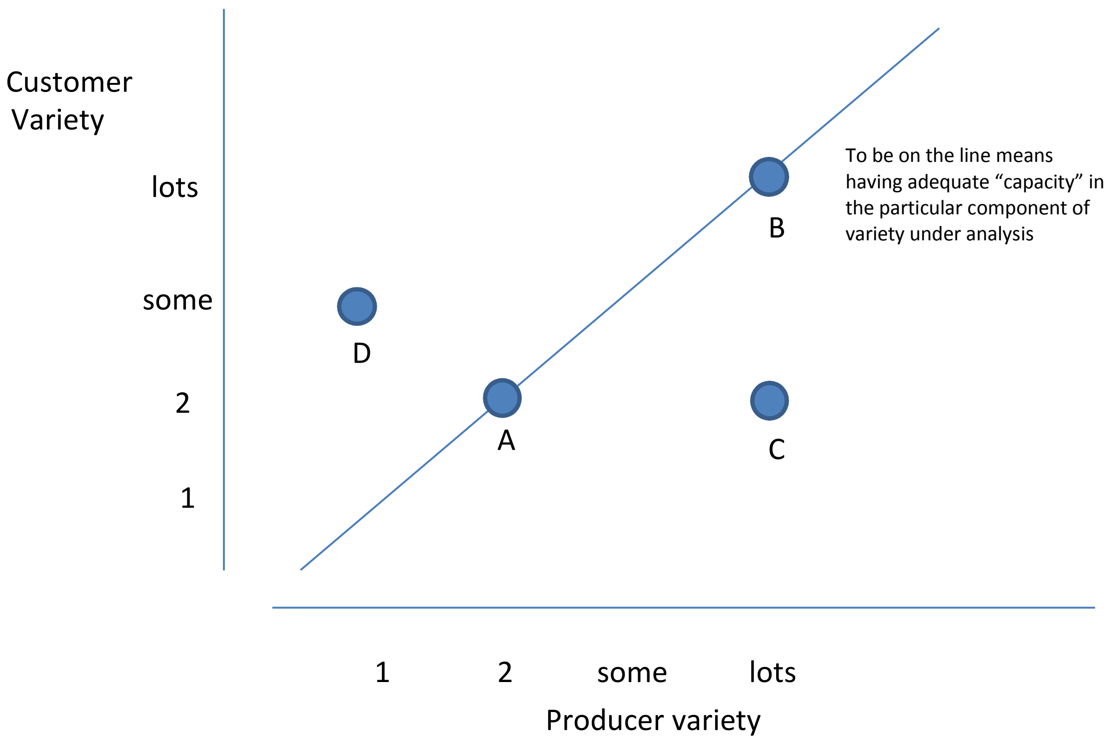

Figure 3 Customer and Producer Variety Matching

ILS matches arrival variety through a scheduled pickup and the ability to quickly reorganise their pickup vans and through the initial contract only allowing very limited types of request variety. In both these instances the position is low on each axis. However, it is in the variations in weekly volumes that their greatest risks occur. Having too many resources, in this case number of staff (the plant is highly automated), for the amount of customer variety introduced into the producer system is obviously expensive and incurs extra costs that would not be matched by revenue.

This would threaten the long-term viability of the system. In recent months ILS has responded to these fluctuations in volumes through employing staff on an part time hourly basis where they call in low-cost labour to help with the sorting process when volumes are higher than anticipated and lay off those staff when volumes are lower than anticipated.

Finally, so far, we have not discussed Frei's subjective preference variability which is reflected in Ashby's model as the outcome. Discussions with ILS staff and customers identified two essential components of the outcome; on time and clean. If the Linen is not clean or is torn then it is returned by the customer and hotel customers in particular soon begin to complain. ILS try to prevent this occurring by washing all the laundry to the highest possible standards and by replacing on average 11% of the laundry yearly. This does incur unnecessary costs for example in chemicals and energy but does mean that ILS does not have switching costs for processing at different standards.

If the linen is late then that will have implications for hotel bed availability and if the sterilised bundles are not on time this can affect surgery times. This can happen if volumes are greater than anticipated and cannot be processed quickly enough. However, the risk of this occurring is minimised by risk pooling. ILS achieves risk pooling through their contracting methods. Typically, they will limit a hotel's choice of sheets to white and queen sized, towels are white and of limited range of sizes and hospitals are limited to single sheets and white. They also actively try to reduce the number of different types of tablecloths and napkins. This means that even if the Holiday Inn is full and the Hyatt Regency is empty, they are both using the same sheets and therefore the volume is averaged out across all users. Demand variability is reduced through aggregating demand across 30-40 customers.

6. Summary and Discussion

According to Sampson, service processes are where 'the customer provides significant inputs into the production process'.(Sampson, 2000). Using this conceptualisation of service being defined as the interaction of customer and producer systems this research considers variety as a central concept in the design of service systems.
In researching the notion of variety within systems the key theoretical model is Ashby's law of requisite variety (Ashby, 1969) which states that there has to be as much variety in the regulator as in the disturbance if the systems is to remain viable and that 'only variety can absorb variety'. Despite its apparent simplicity the law can be challenging to apply.

Various authors have tried to operationalise and test Ashby, using quite different research methods and approaches with limited success. None of these approaches have been widely adopted. Yet there are some insightful notions about the qualities of variety which bear further examination eg Franceso and Wiers' (2006) consideration of the frequency of a state and de Raadt's examinations of the importance of the spread of the states and their identification that some states have greater impact. We have added these to other qualities of variety such as Ashby's variety is a count of the number of states a system can be in.

In operationalising the components of variety we propose that the disturbance is a vector with many components and we use Frei's (2006) five types as the basis for our analysis. Controversially, we add volume to these types for in the operations management literature (see for example (Slack et al., 2004), volume is often seen as the inverse of variety. In our view volume varies and this variation has a major effect on service design. For Ashby, where variety is simply a count, what is important is the number of states that 'volume' can be in. Those authors who consider volume as the inverse of variety may be simply looking at the quality 'frequency of occurrence' as in we get orders for large quantities of the same thing (low request variety) or we get orders for small quantities of many different things.

There are many components of the variety vector, however to provide an illustration of our disturbance model we sought a case organisation which would provide both a significant and on-going access and also that would a-priori have a very limited set of variety components. The case study, ILS a laundry based in an isolated city in Australia has seen very little change in its market in 20 years, with no significant new organisations emerging. From our preliminary discussions it emerged that ILS actively seeks to reduce request and arrival time variability and does not engage in co-production.

We analysed ILS' variety using our disturbance model of three components and five qualities. We considered disturbances according to whether they never changed, changed a little, changed a lot but were not a major problem and those that changed a lot and had a considerable impact on the producer system. This simple categorisation revealed the central importance of the volume component and that volume has the greatest impact on the design of the service system.

We suggest that there are existing theories in the operations management literature that can provide insight into how to deal with arrival and response variety. Little's law (Slack et al 2004) has many forms but essentially deals with alternative forms of servers and queues and arrival states, that is arrival variability. More challenging is response variety. Parnaby (1987) has suggested an approach for manufacturing based on his framework of runners, repeaters, strangers. Runners are frequently occurring requests, repeaters are more irregular and so on. According to Parnaby the response system for runners should be a dedicated flow line with the other three being dealt with through an alternative process and sharing of resources. The alternative response is that advanced by the adherents of the Toyota Production Systems (TPS) who suggest that the best design is to take all variants down one process and to have the process blind to variety. Both these alternatives are legitimate Ashbyian responses the question remains as to which produces the most viable outcome and under what conditions. Neither approach would appear to deal with "unknowns" (Godsiff et al., 2009) which it might be argued are more common in a service environment than in product based environment.

There are also some general implications for the optimum point of operational performance. Ashby's law suggests the matching (see also Frei) of customer disturbance and producer response. This would imply a performance line where the two are matched. What are the implications from being away from the line, can we assess how much an organisation needs to move to return to the line? What does this mean for the value proposition and for resources (labour and capital)? Beer in his later adoption of Ashby suggest strategies based on attenuation (again see Frei) but also amplification. There is little literature on the strategy of amplification in the context of variety eg mass customisation. Amplification would suggest that it is possible to have viable positions where components of customer variety are greater than that provided by the producer system. Further elaboration of the model might provide organisations with the ability to choose between alternative system designs based on an assessment of variety.

Operationalising variety is a considerable challenge, in particular since there are so many definitions of variety (many are implicit) in the literature and that Ashby's disturbance includes anything that affects the producer system. Our initial set of five disturbance components requires much further thought, eg is the list complete and are the components independent and orthogonal? The development of a more complete set of components is an important next step.

There are also many questions to be addressed with Ashby's formulation eg the regulator does not remain constant, managerial knowledge becomes codified and developed and what is initially a disturbance that requires a response can over time become a minor problem.

We acknowledge that there may be weaknesses in this approach to operationalising Ashby's work; however it does have the redeeming feature that it places the customer and producer system together and considers the implications of the interaction in a service system. We recognise that our findings are tenuous; this is a highly complex area. If researchers can develop a typology of components and qualities of variety we may begin to explore how we can better design service systems. A test of this framework would be to analyse a number of organisations and consider what we would predict would be their major service systems design problem.

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Appendix A

Definitions of vary, variable, variability, variance, variant, variation, variety, various
Source: Collins English Dictionary; 6th Edition, 2003. Glasgow, GB

	Verb / determiner	**adjective**	**noun**
vary	To undergo or cause to undergo change, alteration or modification; be subject to change; to give variety to		
variable		Liable to or capable of change; lacking constancy;	Something that is subject to variation having a range of possible values
variability			The ability to be variable
variance			The act of varying or the quality, state or degree of being divergent; discrepancy; a measure of dispersion
variant		Liable to or displaying variation, differing from a standard or type	
variation			The act, process, condition or result of changing or varying; diversity; an instance of varying, or the amount, rate or degree of such change
variety			The quality or condition of being diversified or various, a collection of unlike things, different form or kind within a general category
various	Several, different – he is an authority on several different topics	Of different kinds, diverse, displaying variety	