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THE APPLICATION OF LOCAL RULES IN SELF ORDERING SYSTEMS

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Abstract

This paper examines the imposition of "local rules" in the mail sorting rooms of Australia Post. Local rules are patterns of behaviour at a micro-organizational level. They are used where "attempts (by an organizational subunit) to optimize its own selfish benefit, even if that is harmful to the whole, can lead....to the welfare of the whole organization." (Kauffman, 1995). Fitness landscapes and classifier networks are used to examine the emergence of local rules in the workplace. Mail sorting rates shows a clear catastrophe shift as PDOs apply local rules to maximise gains inherent in the pay structures. Such behaviour is close to that predicted by Kauffman in computer simulations of lattices and may be indicative of the application of local rules in organizations. The implications are that behaviour in social systems may be dictated by systemic and emergent processes which are outside immediate management control. A further implication is that organizations may be structured, to a significant extent by such local rules.

THE APPLICATION OF LOCAL RULES IN SELF ORDERING SYSTEMS

INTRODUCTION

The wide-spread use of down-sizing and right-sizing appears motivated by a fundamental belief that "leaner, meaner" organizations have the greatest chance of survival in the business jungle. The use of the metaphor is informative. It implies that the forces of evolution, selection and competition, are at work in the ecological system of business. Further, it implies that managerial intervention in this ecological system may speed up the emergence of more adaptive organizations and increase the chances of survival. Such interventions occur at the macro-organizational level where single major structural adaptations are believed to better equip the organization to deal with a complex and multi-dimensional environment.

This paper uses the ecological metaphor and work done in the biological and computer sciences to examine the emergence of successful adaptive organisms (or organizations). It discusses how such emergence is part of a highly local, rather than managerial, macro-organizational, response to the dynamic landscape in which human organizations operate. It will be suggested that stable and perhaps optimal behaviour for the organization is an emergent phenomenon based on "local rules" whereby individual agents in the organization seek to maximise their own individual payoffs. The discussion examines ideas of competition, selection, adaptation and emergence and relates them to an organizational context using behaviour observed in work practices in Australia Post, the Australian national mail authority.

THEORY

Dennett (1996) suggests that all processes are essentially algorithms which have three specific attributes. Algorithms produce outcomes from process. His example is a coin tossing competition. In each round, the winner progresses to the next round. In this algorithm selection is based on chance and, if 1024 people start, the ultimate winner will have won ten consecutive tosses. The fitness of the winner to survive is based purely on chance.

The outcome is inherent in the system. This is not to argue that the best coin tosser has emerged but simply that one will survive to the final round. The chances of this same winner emerging in the second playing of the competition are 1:524288.

If through the introduction of an element of competition, the game is changed to tennis, where there is a significant component of skill, then the chances are that the best, and not just a lucky, player will win. Now, the fitness to survive is based on an adaptive skill. The skill, playing tennis, has global application in the competition.

If the rules of the competition are changed again, so that round one is tennis, round two wrestling, round three quoting Shakespeare, round four growing roses etc, a different winner will probably emerge. Now the most adaptive tennis-wrestling-Shakespeare-quoting-rose-growing agent will win, the one best able to meet the local conditions at each round. It has become a matter of local adaptation to the local competitive environment that produces a global winner. It is the individual best able to optimise their outcomes at each step of the competition who wins overall.

A different metaphor for selection is used by Kauffman (1989) who describes organisms operating on a "landscape" where the strategies inherent in local adaptation and selection produce "fitness peaks" rather than a knock-out competition. Organisms go on "adaptive walks" as they test survival strategies. When these strategies are successful they climb these fitness peaks (proceed to the next round) as they evolve to better levels of adaptation. On other adaptive walks, organisms remain trapped in low adaptation "valleys" and become extinct (do not proceed to the next round).

As organisms seeking out their adaptive fitness peaks, they are involved in interactions with other organisms with whom they are competing or co-evolving. Thus these landscapes constitute sets of dynamic interactions between competing organisms where the fitness peak defined by one organism during an adaptive walk will serve to define the fitness peak other organisms with whom it competes or co-evolves. In the case of competition of a predator, one peak (the development of sustained running speed) may create a "valley' of low optimisation for a slower prey. In the case of co-evolution, the creation of this peak and this valley will create a fitness peak for a scavenger. Once the prey evolves greater running speed that the predator, the fitness peaks for both predator and scavenger are modified.

Kauffman proposes that dynamical systems theory provides a framework for describing such systems where many interacting parts define the parameters of the landscape. Unlike normal landscapes which are three dimensional, fitness landscape occupy "multi-dimensional" space. The dimension of the landscape are defined by broad ecological factors, such as climate, vegetation, density of population, terrain which remain relatively constant over time whereas the dimensions of the fitness peaks are defined by the parameters of the strategies of the individual organisms which will be subject to relatively faster change. Thus, the ability of a prey to outrun an ambushing predator defines the fitness peaks for both animals. As the predator evolves to run faster and to hunt in packs the fitness peaks of both organism, and hence their chances of survival are re-defined.

Dynamical systems theory suggests that, in dynamic landscapes, behaviours such as those of the predator, tend to "box" into small regions of behaviours in the total space of all possible behaviours. These regions are the equivalent of a set of interacting fitness peaks. These regions are called attractors. These regions of behaviour are asymptotic and indicative of long term behaviour and constitute what Kauffman terms "spontaneous order". In the case of :strange attractors", these regions may be defined by a relatively small number of parameters compared to those defining the larger multi-dimensional space. The emergence of attractors is a special property of dynamical systems where there are high levels of interaction based on strategies that are highly specific to the locality of the agent. Such strategies can be seen as the "local rules" of selection.

In passing, it should be noted that the metaphor of the fitness peak to describe an attractor is not universally used. Gell-Mann (1994) comments that while biologists use height as a measure of fitness, the reverse convention of attractor "basins" as regions of fitness is common in many other fields. While the metaphor is different, the idea is identical. There are regions in multi-dimensional space into which organisms fall as their evolutionary fitness improves.

This process of emergent or spontaneous order from local selection has been observed in computer simulations of interactive processes. In an analysis of simulated strategies (or rules) used in the Prisoner's Dilemma Feldman and Nagel (1992) observed "widespread local co-ordination" similar to that found in decentralised economic processes. This emergent behaviour is a response to the need for each agent to respond with a "cooperate or defect" strategy and is similar to that suggested by Kauffman.

Huberman and Hogg (1993) discovered "emergent computer ecologies" in distributed computer networks where individual agents (computers) would bid for tasks rather than have them allocated by a central managerial system. They found that the computers would bid for access to resources using "arbitrarily defined local rules" that were designed to maximise payoffs for the individual agent. Once rewards for successful behaviour were introduced the proportion of successful agent increased and stabilised the system. They suggest that this behaviour, where agents optimise payoffs from a local perspective, is analogous to the appearance of organized behaviour in biological and social systems.

Thus the emergence of successful payoff-optimising agents is based on their ability to adapt to specific and local conditions. This is not a central management decision process and no overall organizational structure imposed on the system. It is as ??? described it "order for free".

Holland (1989) believes that many organizations do not have repetitive or easily recognised patterns of behaviour. This is because they are intrinsically dynamic, far from global optimum (always room for improvement), and continually adapting. He terms such organizations ANNs (adaptive non-linear networks) which use a "classifier system" as their means of adaptation. In his description of the classifier system, Holland refers to "rules". These rules are attempts at adaptation to environmental demands. These rules are the "local rules" of behaviour that are used by agents in an ecological landscape. The classifier system tests the fitness of each rule of behaviour in the ecological landscape where the fittest ultimately survive.

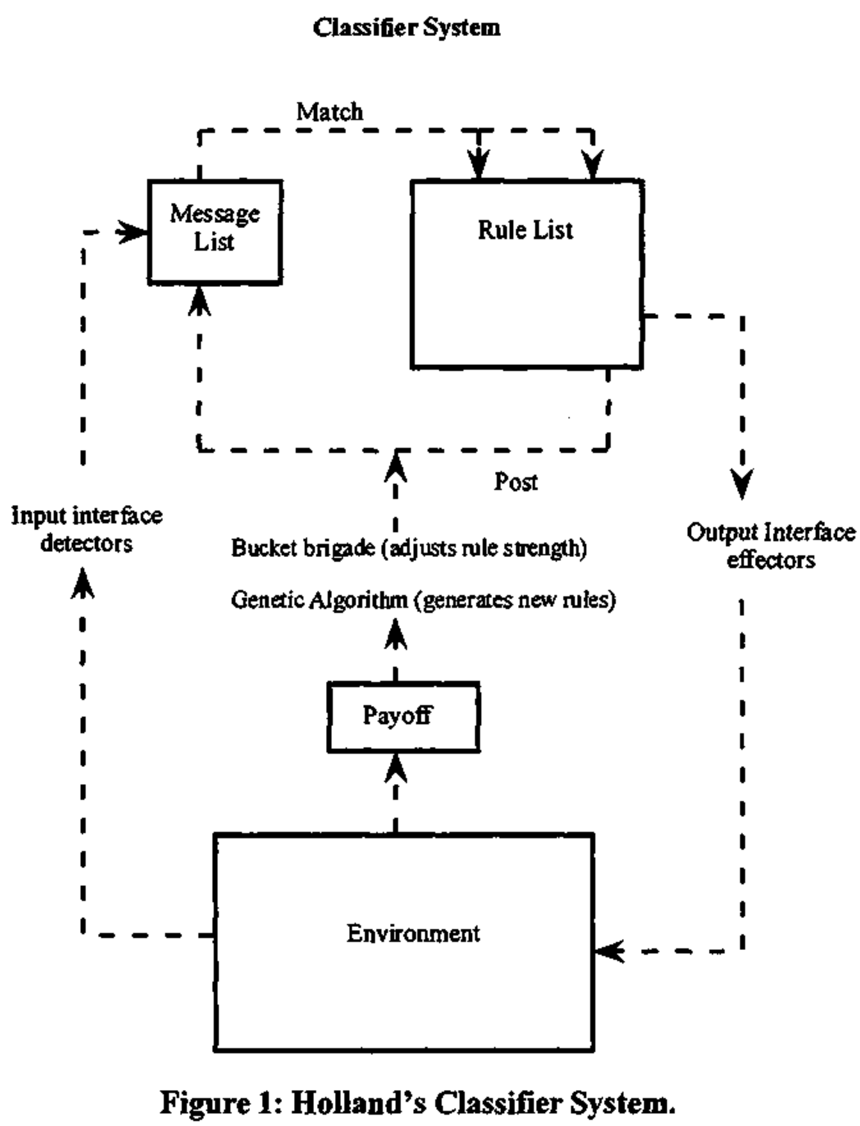


Figure 1: Holland's Classifier System.

The environment sends messages to the message list, a bulletin board of "things to be dealt with". These messages are matched against rules from the rules list. The rules are made up of two components: on the left is the condition on the right is the action If the message has conditions are satisfied by the rule, the rule can send a message to the output interface and post a message back to the message board. Messages that provide the most specific satisfaction of the messages conditions are posted.

Consider the situation where

Message	1	1	1	1

is received from the environment and compared to the left hand side condition of a series of rules.

	Condition				Action			
Rule A	1	0	1	1				
Rule B	1	0	0	1				

Rule A is posted rather than Rule B because it satisfies three of the messages' conditions where Rule B only satisfies two. As Rule B has not posted this message, it would drop off the rule list unless it is able to satisfy another message. As Rule A is posted its effect on the environment is tested by the payoff which is the reward for its successful interaction with the environment.

Both Rule A and C satisfy the condition, and thus both will be posted and the action section of the rule will receive, or not receive, a payoff from the environment.

Message	1	1	1	1

	Condition				Action			
Rule A	1	0	1	1	1	0	0	1
Rule B	1	0	0	1	1	1	1	0
Rule C	1	0	1	1	0	1	1	1

	Requirement			
Environment	1	0	1	1

In this case, Rule A matches three conditions of the environmental requirement whereas Rule C matches only two. Accordingly, Rule A receives a payoff and Rule C does not.

The "Bucket Brigade" adjusts the rules strength according to the size of the payoff from the environment. The rule then returns to the Rule List via the message list with its adjusted strength. Its ability to post messages in the next round is now based on its rule strength (based on payoff) and its specificity to the incoming messages. In our example, Rule A survives and Rules B and C become extinct. In successive postings, it would be expected that Rule A which only matched three environmental conditions, would be replaced by a "fitter" rule which satisfies all four conditions.

Kauffman (1989) believes that Holland's classifier systems appear to be a remarkably powerful family of adaptive systems and a close analogue to an ecosystem where the fitness of each rule depends upon how these rules interact with the external environment to extract payment (via payoffs). In this system, selection acts locally on each rule allowing it to replicate only according to its fitness.

Over time, the fittest rules, those providing the greatest payoff from the environment, survive. Those which provide little or no payoff are not used and become extinct. There is now emergent behaviour based on rules that have received as payoff at the local level local. These provide Kauffman's fitness peaks, (Gell-Mann's equivalent attractor basins), regions where relatively stable patterns of behaviour can be observed. These regions are defined by the emergent, fittest local rules. The definition of these accessible regions implies the definition of inaccessible regions, those where survival is unlikely and extinction highly likely. In social systems, this simply means there will be certain behaviours that are frequently observable, because they produce payoffs or rewards and other behaviours that are not observable because they produce no payoffs and perhaps punishments. It is likely that in social systems, there may be more than one behaviour that produces a payoff given slightly changed conditions. The flight or fight strategies are a crude but simple example. Here the behaviour is bi-modal and both produce a payoff whereas a "negotiate" strategy may not. The behaviour here is bi-modal, fight of flight. this bi-modality-modality can be achieved by what Kauffman describes as a "long jump adaptation" where the " long jump adaptation is a process in which many parts of the system are altered or mutated at once; thus the system jumps a long distance across the space of all possible systems" (655). Such bi-modal behaviour is described by the catastrophe model.

The catastrophe shift model describes such shifts from one state or region in space to another. Flay (1978) defined a number of factors that identify catastrophe shifts: abrupt, catastrophe changes between one mode of behaviour and another; abrupt change, or hysteresis, from one mode of behaviour to another with different values of the control factors and an inaccessible zone of behaviour for some of the control variables. The process by which this is achieved is common shown in its simplest form: the cusp catastrophe shift, shown in figure 2.

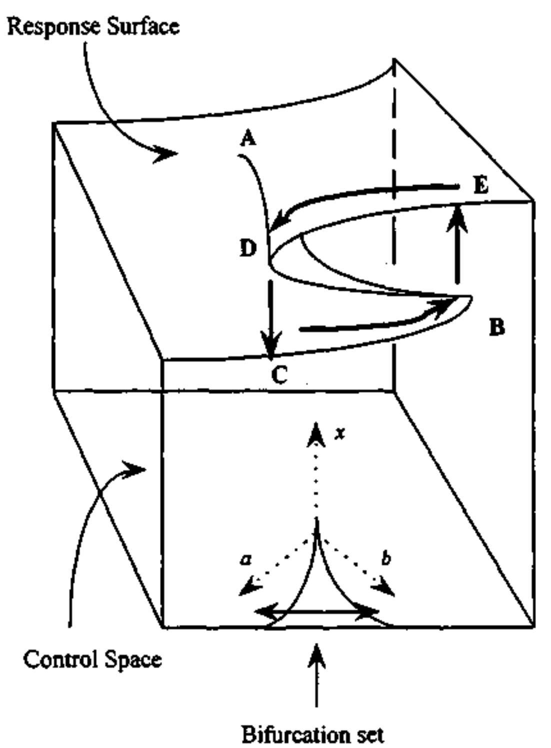
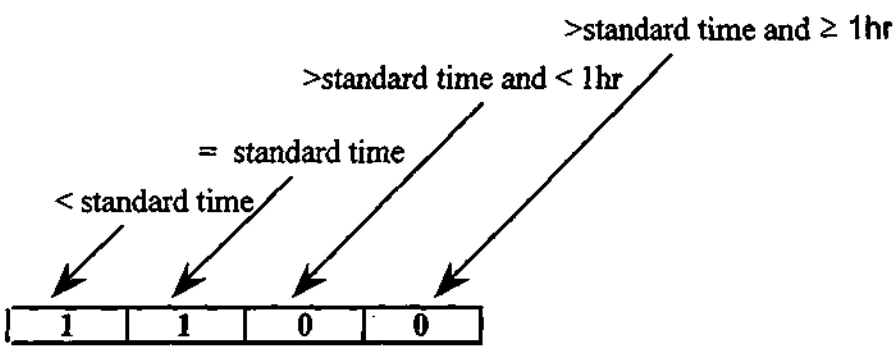


Figure 2. Cusp geometry for a system with two parameters

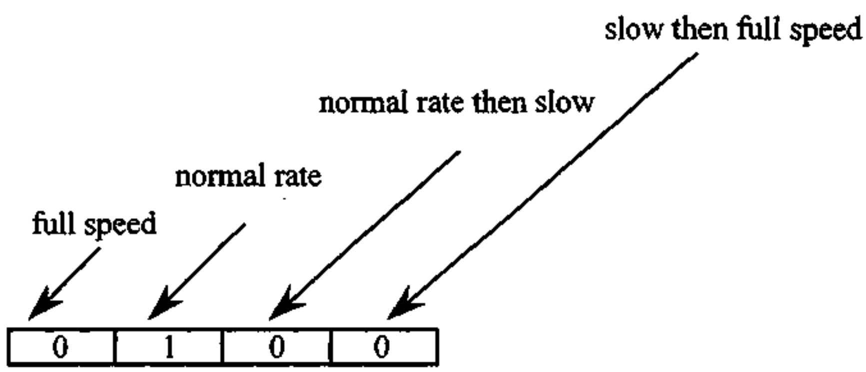
In this figure, a behaviour, derived from a local rule can be in the region on the response surface defined by the area under the fold, ABC. Once the line AB is reached the transition is to the new plane defined by ADE. The inaccessible region is defined by ABD, the region under the fold. The accessible regions in the cusp catastrophe control space correspond to the peaks in the fitness landscape while the inaccessible region correspond to valleys where there is no payoff and where rules and behaviours become extinct. Progression to the region ADE can be achieved by an adaptive walk around B but in the catastrophe model the most likely progression is across AB. The catastrophe model defines two accessible regions. When these region equate to fitness peaks, the payoffs inherent in Holland's classifier model ensure that the behaviours rest in one of the two regions.

CLASSIFIER SYSTEMS IN AP

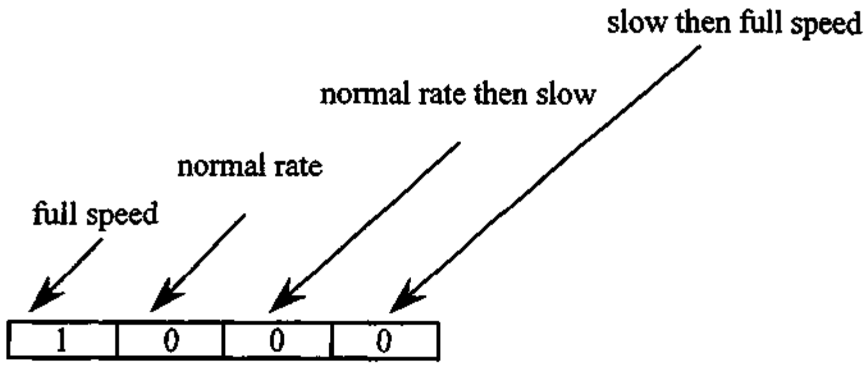
The distribution of times spent working are suggestive of the adaptive walks, where various work strategies are tested to maximise payoffs given the volumes of mail to be sorted. Such strategies may include time wasting behaviours that will extend the time taken to sort the mail. Applying Holland's classifier system a binary code for incoming mail could be:



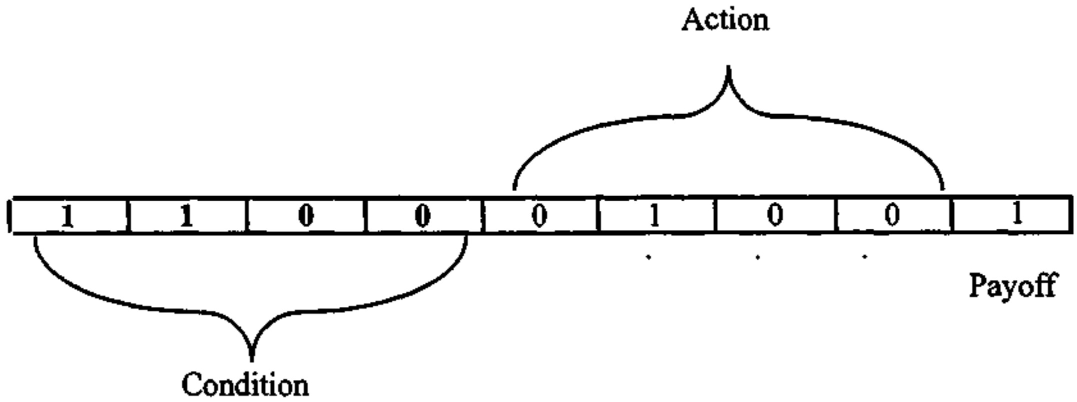
In this situation, there is enough mail to work a standard day but not enough to work overtime. The amount can also be sorted in less than standard time. Given this coding, there will be numerous codes. This one allows the PDOs to adopt to possible behaviours coded as follows:



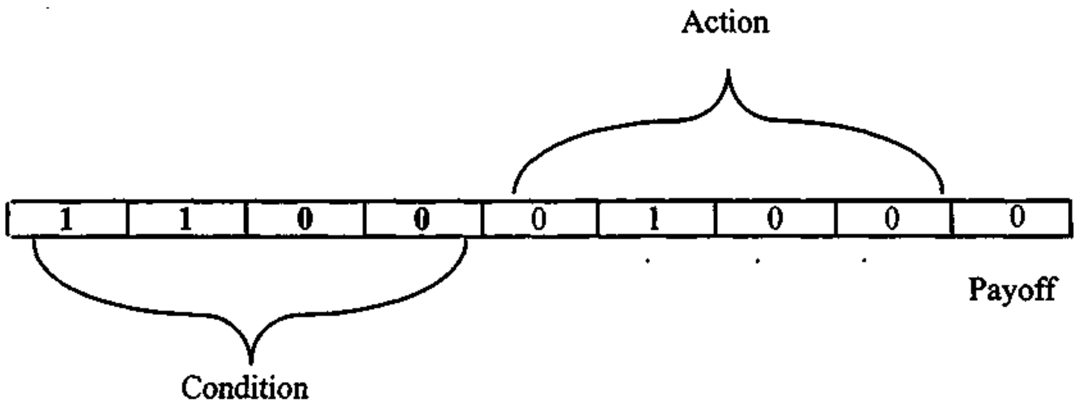
an alternative to this would be:



The two rule would combine condition and action so that the incoming message from the environment would be matched with a rule with its attendant action



This rule which would have the outcome of working at full speed. The payoff is going home early with a full days pay whereas working at the normal rate provides no payoff in terms of going home early or getting extra money.



It is clear that the rules used in AP can be analysed in terms of Holland's classifier systems. The strength of this analysis is that it provides a methodology for the analysis of the emergence of such rules and the consideration of rules that may have been tried but provided no payoff. It is probable in this case that the rule: "Work at constant rate to leave on time" was tried but as it provides no payoff against the other rules, it became extinct.

Classifier systems allow for detailed analysis of local rules and provide a means for understanding the evolutionary process by which adaptive behaviour is refined in the face of payoffs. Inherent in this idea is that the local rules are defined only by testing their fitness. The graphs shown below indicate that there must have been days when the strategy for getting a "mealie" did not quite work but that over time, the PDOs became more adept at getting their "mealie"

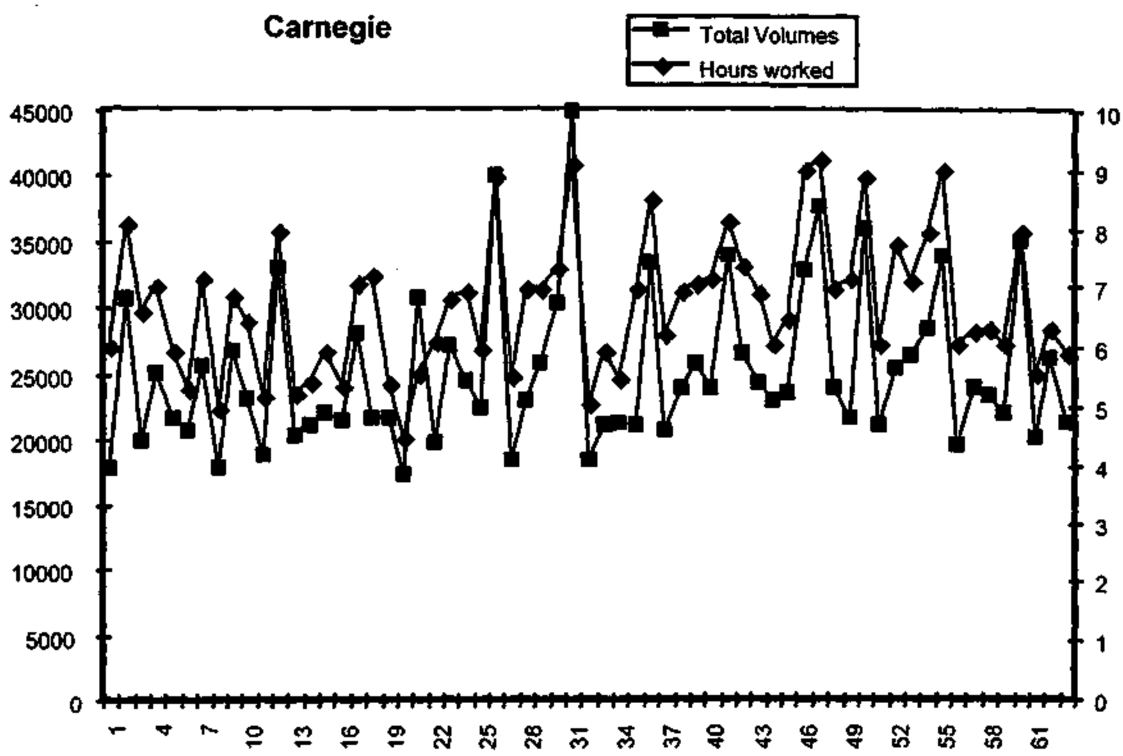


Figure 3: Carnegie Work/Volume

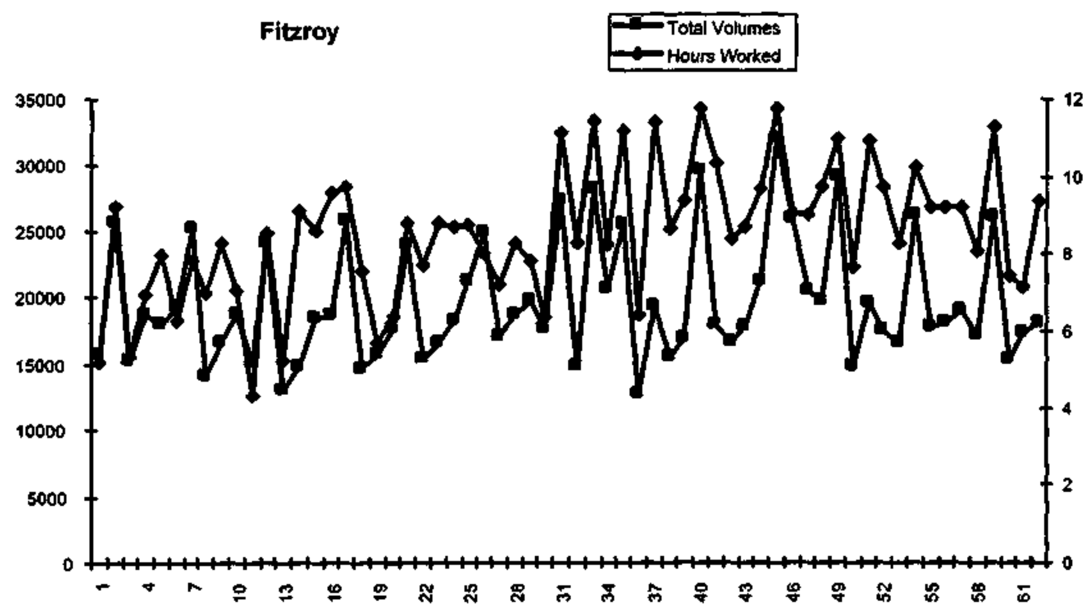


Figure 4: Fitzroy Work/Volume

Unfortunately, the data does not allow analysis of adaptation of behaviour over time but the theory would suggest increasing bi-modality in time worked as PDOs became better at maximising payoffs through the use of local rules.

THE IMPACT OF LOCAL RULES ON WORK RATE

This section seeks to ascertain whether or not local rules influence work rate in the postal services. Local rules are most likely to be manifested as bifurcations and other nonlinear characteristics.

To illustrate this point, consider the relationship depicted in Figure 1. The abscissa represents the amount of work that must be executed. The ordinate represents the time required to complete this work. In this case, the two variables yield a linear relationship. That is, raising the work load always augments the time required to fulfil this work. Indeed, this situation would arise in many circumstances.

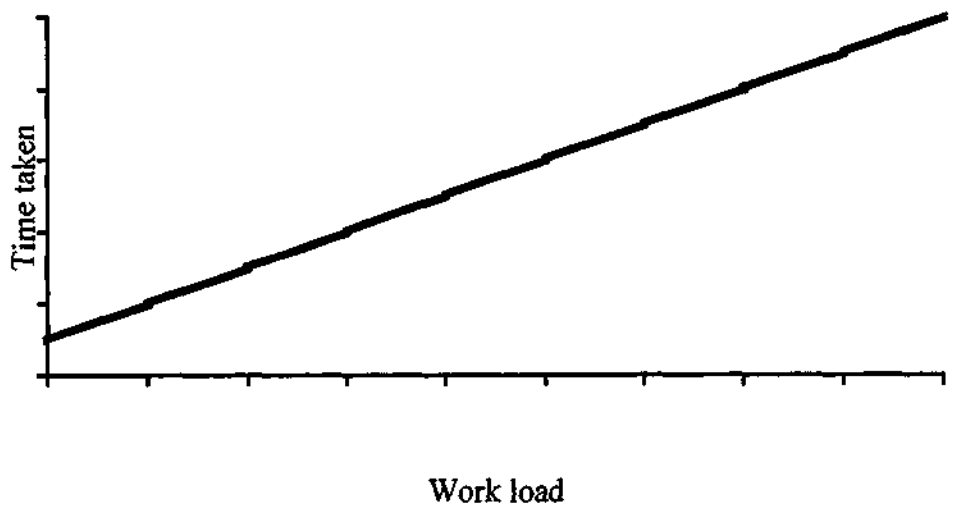


Figure 5: Linear relationship between workload and the time required to complete the work

Nonetheless, in some situations, a more complex pattern may arise. For example, suppose that employees were paid overtime. On some days the work load will be low. In this case, to depart early, employees will complete the work as swiftly as possible. On other days the work load will be elevated. In this case, to ensure that overtime is received, employees will complete the work with less haste. These considerations yield the relationship depicted in Figure 2. The left component corresponds to the situation in which employees are working as expeditiously as possible. The right component corresponds to the situation in which employees are endeavouring to receive overtime.

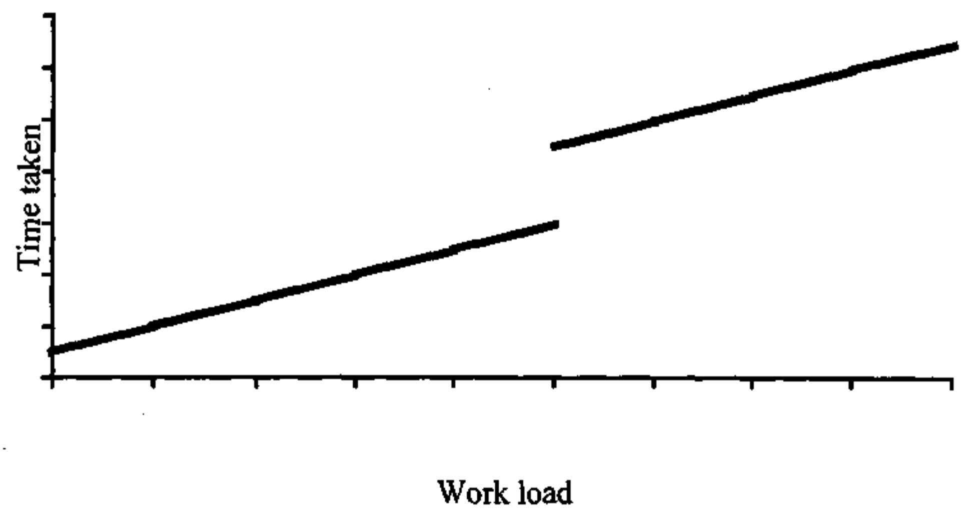


Figure 6: Nonlinear relationship between workload and the time required to complete the work

A mathematical framework, called catastrophe theory, can be invoked to model this bifurcation or split. In particular, catastrophe theory can be utilised to identify any bifurcations. Regression analysis is used to ascertain the relationship between the relevant variables. Significant cubic terms are indicative of catastrophes (ie bifurcations). The absence of any significant cubic terms indicate that bifurcations are not present.

SOURCE OF THE DATA

The data correspond to the work rate of seven suburban post offices. For five of the offices, three months of data were collected. For one of the offices, two months of data were gathered. For the remaining office, only one month of data were collected.

On each day, information relating to several variables were recorded. The most crucial variables are specified below.

1. Mail volumes

2. Predicted and actual time at which sorting begins.

3. Predicted and actual time at which sorting is completed.

Overall, 375 days of data were recorded. Unfortunately, 25 of these days were omitted; these days contained missing data or errors. Accordingly, 350 of these days were subjected to the analysis.

Interviews conducted in AP indicated that there were two fundamental patterns of behaviour for postal delivery officers PDOs. These were in response to the negotiated "award" which sets work rates and conditions for the PDOs. In brief, this lays down that the worker must be paid for a 7.5 day, after this they receive "time and a half" for any extra time. After an hour of overtime a meal allowance, or "mealie" of $30 tax free is paid, in addition to any extra overtime. Given that the hourly pay rate is $11.70 giving average weekly take home pay after tax without overtime is $350

($433 before tax), earning a $30 mealie every day constitutes $150 tax free per week, an increase of 40%. PDOs receive a "standard" day's pay for 7.5 hrs ($81.90) regardless of whether they work the full 7.5 hours. If they work longer than 7.5, they are paid ovetime and onc ethey have worked an hour's overtime, a meal allowance.

FINDINGS

Indication of bi-modality

In the Australia Post situation, the incoming messages are about the volume of incoming mail which will vary from day to day and the number of PDOs available to do the work on that day. This provides the work loading for each (PDO). It is this work loading that constitutes a "message". There is little correlation between post offices work loadings because the mix of mail between letters and parcels varies depending on the location. These messages generate a series of rules which have varying payoffs for the PDOs.

Workload done in:	Rule	Payoff	n
< Standard time	Work fast to achieve fly day	Leave early with full pay	31
Standard time	Work at constant rate to leave on time	Nil	0
> Standard time but < 1hr	Work at rate to meet Standard time + 1hr	1hr overtime	55*
> Standard time and ≥ 1hr	Work to stretch time to >1hr Work very fast to finish as early as possible.	1-2 hrs overtime + Mealie	298

* The application of this rule was specific to four of the seven offices with 75% (n = 41) in two offices. This suggests that this rule is specific to different offices.

This bi-modality indicates that there are two regions or fitness peaks for the strategies used by AP PDOs: going home early, a "fly day" and working overtime and getting a "mealie". The valley, where there are no payoffs, is working a standard day, constituted by the target time. These fitness peaks are defined by the local rules for work rates that the workers use to maximise their payoffs: time worked and average pay per hour.

Given that PDOs are paid $81.90 regardless of how long they work, their average rate of pay declines until they are into ovetime and the possibility of a "mealie". For instance if they can ge the work done in one hour, their average rate of pay is $81.90, for two hours $40.45. However, the payment of a "mealie" makes a significant diference.

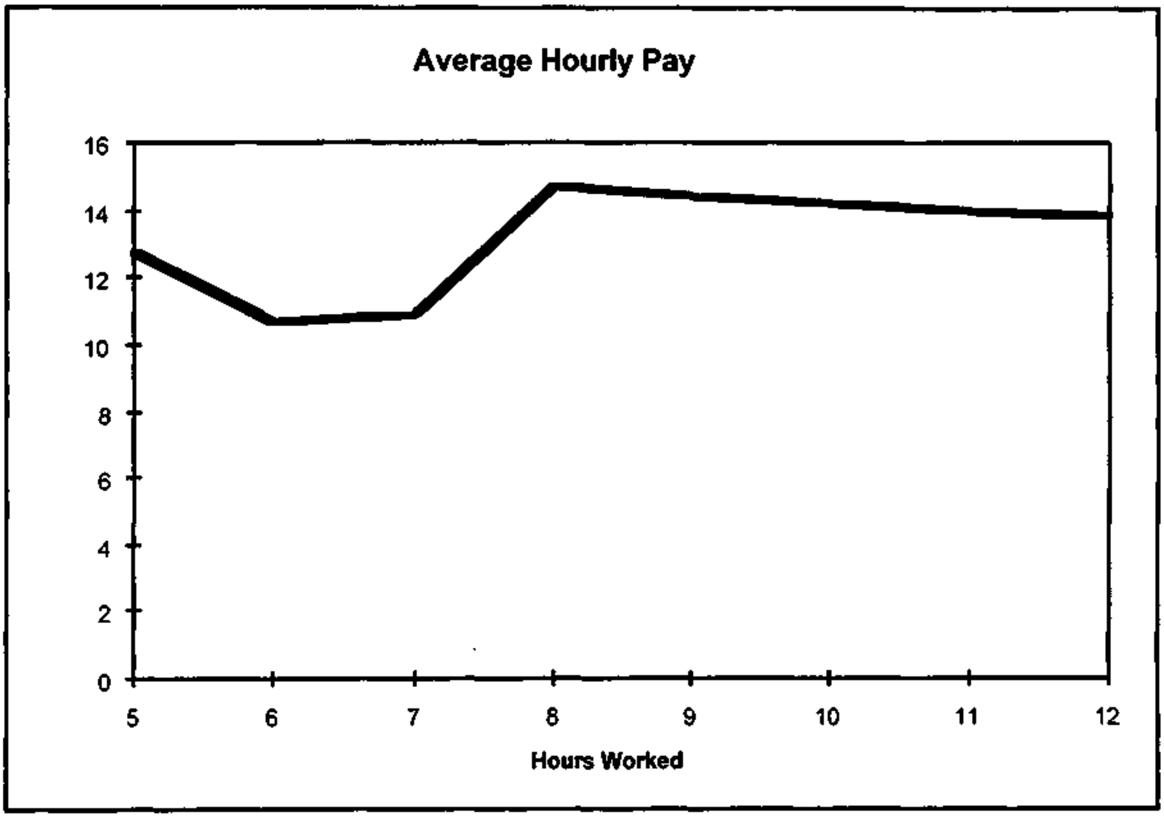


Figure 7: Average Pay

It was rare for work to be completed in less than five hours, so without overtime, PDOs were in a situation of declining returns as they worked between five and eight hrs. In terms of fitness peaks, they must either climb up the graph to the left to maximise hourly returns or reach the plateau on the right created by the payment of a mealie. To gain the same return as a "mealie", PDOs would need to complete a days work in two hours, clearly very difficult. Thus the greatest fitness peak lies in the area after eight hours work and this is the region where work was done most frequently.

However, the distribution of mail to be sorted generally does not indicate such bi-modality. A representative sample of four mail centre shows that the distribution of skewed to the lower end of the scale.

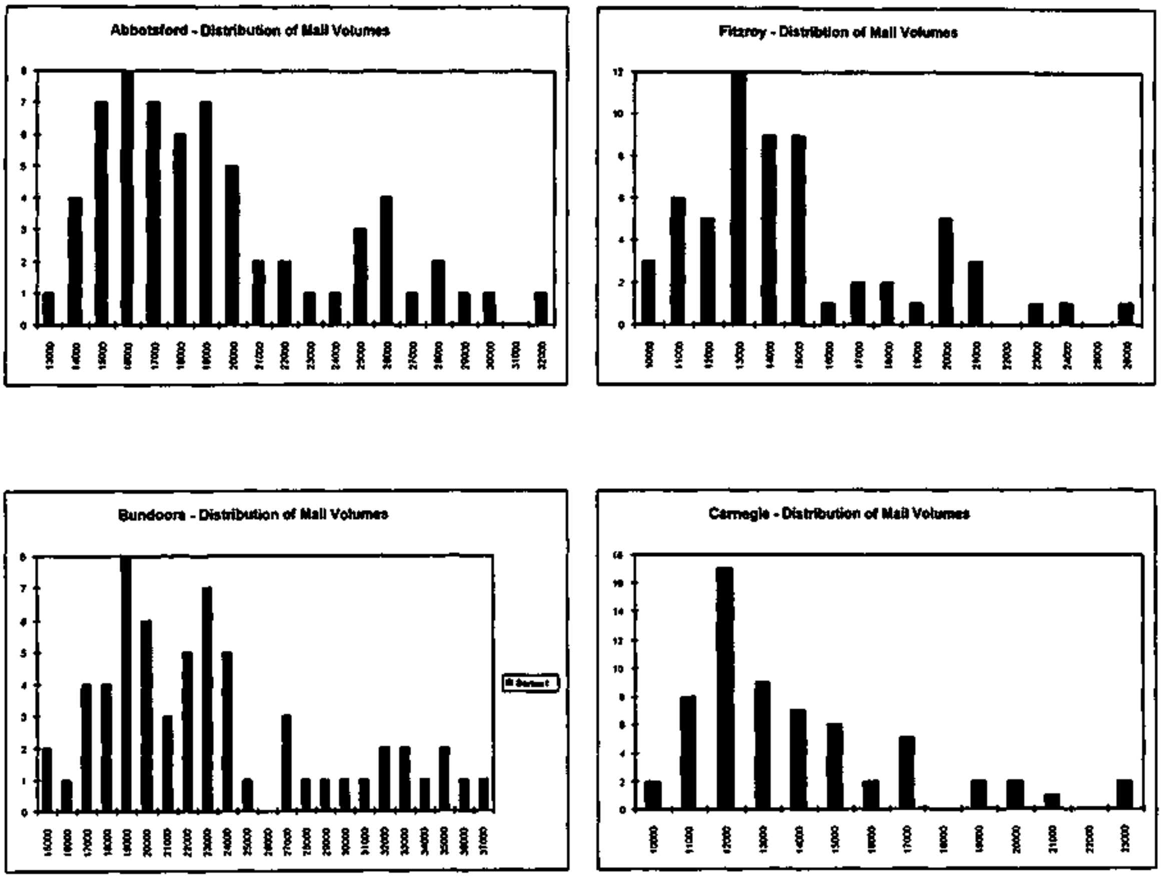


Figure 8: Distributions of Mail Volumes

This suggests that the time spent to sort the mail is not dictated by the volume of mail but by the local rules set by the PDOs. These local rules are a response to the wider work environment in particular the pay rates and conditions negotiated for the PDOs. These local rules have produced a interesting pattern of behaviour. PDOs work at a reasonably constant rate for volumes for volumes of mail that can be completed under target time. However, once a "mealie" has been achieved, the work rate increases to finish as quickly as possible. Thus, the greatest rates of productivity are achieved at the end of the day once when the maximum payoff has been achieved.

When mail centres are compared, the behaviour is similar. This suggests that the local rules of behaviour are in fact a response to the general environmental conditions and not behaviour specific and idiosyncratic to each centre.

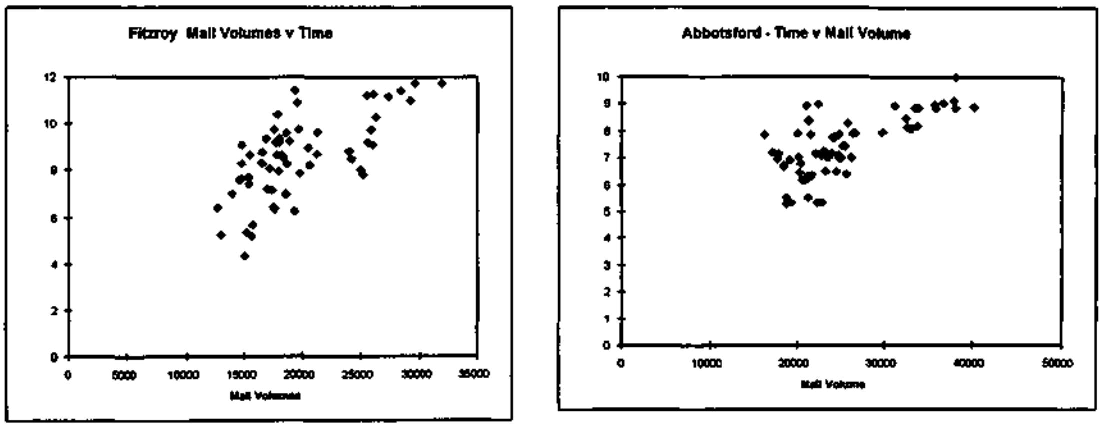


Figure 9: Hours Worked v Mail Volumes

These graphs suggest that up until 7.5 hrs has been worked, there is a linear relationship between time and volume, the more mail the longer the time. However, once the "magic mealie" has been achieved, the work rate is increased to finish as quickly as possible. For instance, in the Carnegie centre, volume between 33,000 items and 45,000 will generally be sorted in nine hours. This constitutes a variation of 36% in productivity rates at the higher volumes.

VARIABLE SELECTION

Key variables

This study was primarily designed to investigate the relationship between mail volumes and the time required to complete this work. Hence, the two principal variables were:

1. Mail volumes

2. Time taken (hours)

Time taken was calculated by deducting the actual time at which sorting commenced from the actual time at which sorting was completed. Of course, several variables could potentially modify the relationship between average workload and time taken. The remainder of this section is designed to identify these variables.

CUBIC EQUATION

Delineation of the equations

To reiterate, the presence of significant cubic terms is indicative of catastrophe models. This section determines whether or not the relationship between time taken and average workload entails cubic terms. To accomplish this objective, the following equation was examined:

$$Æ_z = ß_0 + ß_1 z_1^3 + ß_2 z_1^2 + ß_3 b z_1$$

where $Æ_z$ = Work Rate

z_1 = Mail Volume

b = Hours Worked

When the coefficient associated with Mail Volume^3 departs significantly from zero, the relationship between time taken and average workload is assumed to conform to a catastrophe model.

Results

Ridge regression was utilised to estimate the coefficients (Hoerl & Kennard, 1970). These coefficients were estimated on six occasions. On five of these occasions, the estimates were based on data derived from one mailing centre. In particular, the following mailing centres were examined in sequence: Abbotsford, Bundoora, Carnegie, Fitzroy, and Thomastown. On the final occasion, the estimates were based on data derived from all five mailing centres

Table 1 reveals the standardised Beta coefficients associated with the cubic terms for each of the six occasions. This table also reveals the t and p value pertaining to each Beta coefficient.

Table 1: Beta coefficients associated with the cubic terms in each equation.

	Standardised Beta Coefficients	t	p
• Abbotsford	0.159	5.226	<0.001
• Bundoora	0.197	8.700	<0.001
• Carnegie	0.238	7.660	<0.001
• Fitzroy	0.216	8.445	<0.001
• Thomastown	0.220	8.494	<0.001
• All five centres	0.145	13.033	<0.001

Hence, each mail centre, apart from Thomastown, provided evidence of a catastrophic shift.

These results indicate that employees work at a constant rate when the average workload is below a critical value. When the average workload exceeds this value, the rate of work rises rapidly. This finding suggests that employees do not strive for overtime. Instead, this finding perhaps suggests that when meal allowances are attained, the employees then work is rapidly as possible.

CONCLUSIONS

This analysis supports the case that local rules are defined in response to local conditions. In the specific case of AP, these rules are the key determinant of the rate at which the PDOs work. This sorting rate is counter-intuitive when considered against the amount of mail to be sorted. In this case, large amounts of mail are sorted in the same time as small amounts. This is because the landscape provides two fitness peaks for sorting rates, one which achieves a "fly day" and the second which achieves a "mealie". There are indications that these rules are used in geographically dispersed centres, a further indication of their local evolution in response to global working conditions.

The findings of this paper also suggest that the models that are used to examine fitness landscapes in biology and the techniques of classifier systems used in the analysis of the emergence of these landscapes may have application to research in social systems. There is also the suggestion behaviour may be dictated by a search for optimal payoffs given the parameters of the landscape and that these will be essentially "local rules". Such local rules are the adaptive walks on a fitness landscape.

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