Chapter 4
On Managing Complexity: Variety Engineering

Abstract We, as individuals, are dealing with complex situations, that is, with situations challenging us with a large number of states changing rapidly and unpredictably over time. In all these situations to perform effectively we have to manage the complexity of the situation. This chapter is dedicated to explore principles for managing complexity. We take the view that in general managing complexity refers to our ability to achieve an adequate performance in particular situations of concern. Their boundaries are defined by the purposes we ascribe, implicitly or explicitly, to them. So, in this chapter we explore how we ascribe purposes to situations and why this is important for managing their complexity. The concepts and detailed methods we explain in this chapter are known as variety engineering, which is the key concept that guides our operational design of organizations.

We mentioned in the previous chapter that we could identify many occasions in our daily lives in which we are challenged by situations that appear to us as complex and we would like to be able to cope with them. Daily tasks that we perform in our regular jobs are good examples of those. A general manager that is managing a company, a production engineer that is in charge of running a control system for a production line, a professor who is running an undergraduate course, a doctor who is performing an organ transplant surgery, a politician who is carrying out her political campaign for the next general election, a prosecutor that is investigating a case of multiple bank frauds, a computer programmer that is implementing a visual interface to navigate through the Internet and a child minder who is in charge of managing a local nursery are but a few examples.

These are examples of individuals dealing with complex situations that are challenging to them, with often unpredictable changes over time. In each situation they have to manage the complexity effectively.

Let us start by saying that in general, managing complexity refers to our ability to perform well in particular tasks. We focus our attention on these tasks by ascribing, implicitly or explicitly, a purpose to situations of concern. Let us explore first with more detail how we ascribe purposes to situations and why this is important for managing their complexity.

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We may ascribe tacit purposes to what we do simply by doing certain things and not others. This is what Argyris and Schön (1978) relate to *theory-in-use*. But we may also ascribe a purpose to our actions in an explicit way. This, however, may vary drastically from individual to individual even when referring to the same actions. In his book about Perestroika, Mikhail Gorbachev tells us a relevant story: 'Everything we are doing can be interpreted and assessed differently. There is an old story. A traveller approached some people erecting a structure and asked one by one: "What is it you're doing?" One replied with irritation: "Oh, look, from morning till night we carry these damned stones . . ." Another rose from his knees, straightened his shoulders and said proudly: "You see, it's a temple we're building!"' (Gorbachev 1987).

Situations do not have purposes of their own. We, as observers, create meanings as we ascribe purposes to situations of our concern. As participants of shared tasks, while interacting with each other, we ascribe purposes. When we reach agreements about the meaning of a situation, we may concentrate our efforts on producing it by effectively carrying out aligned activities. When there is alignment between individual purposes (i.e., the meaning we ascribe to our actions) and situational purposes (i.e., the purposes we ascribe to a shared task), people feel more committed, their motivation is likely to be stronger and their performance better. Here is when the management of complexity appears as a relevant discipline that can help us in designing and producing effective tasks to pursue our purposes.

In terms of complexity, we often feel overwhelmed by the situations of our concern; there is an imbalance between their complexity and our much smaller individual complexity. In the previous chapter we mentioned that Ashby's Law of Requisite Variety establishes that only complexity absorbs complexity, however, as we also mentioned, this does not imply that to perform well we have to increase our individual complexity to match the complexity of a situation. We have to gather together complexity management strategies that, similar to using a pulley for lifting a load beyond us, allow us to match this situational complexity. Clarifying these strategies is the purpose of this chapter.

Let's use Fig. 4.1 to represent a case of a person in charge of performing a task in a situation. Suppose she has defined a performance criterion as a way to observe her effectiveness. This criterion is, of course, closely related to the purpose she has ascribed to the situation. It is clear that any event that could affect her performance (according to this criterion) should be an issue of concern, that is, is a relevant distinction for her effectiveness. In other words, she needs adequate practices to respond to those events in order to maintain an appropriate performance. We represent these events in Fig. 4.1 by the set of Relevant Distinctions (or perturbations) while the set of Responses correspond to those practices that she has to carry out to perform effectively.

In this diagram the complexity of a situation corresponds to the cardinality of the set of perturbations, that is, to the number of its elements (i.e., 16 relevant distinctions). On the other hand, the individual complexity corresponds to the cardinality of the set of responses (in this case, eight practices). This imbalance of complexities tells us that the individual cannot *control* the situation. In other words, there are

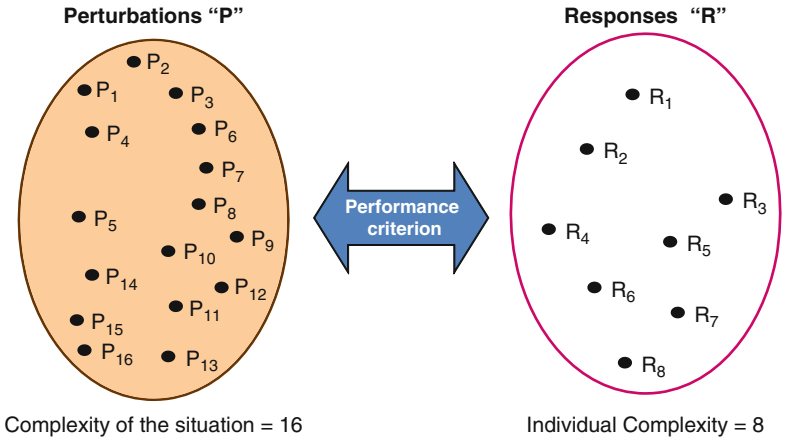

Fig. 4.1 Managing the complexity of a situation – complexity imbalance

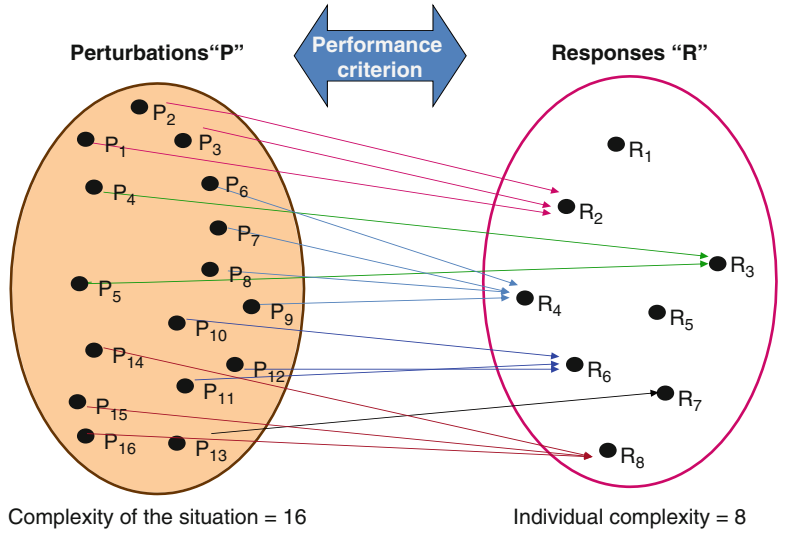

Fig. 4.2 Managing the complexity of a situation – matching complexity

events for which, if they materialize, there will not be an appropriate response. This suggests that the only way to assure adequate performance in this situation (based on the defined criterion) is that the two complexities match; this is precisely Ashby's Law of Requisite Variety that we mentioned above. However, as we suggested before, this law requires interpretation.

Notice that if we redesign practices in such a way that each one can take care of several relevant perturbations we could regain control of the situation as shown in Fig. 4.2. Here, for each perturbation we have an adequate response. On the other

hand, responses or practices that do not match perturbations, such as R_1 and R_5 in the diagram, are irrelevant practices in this domain of action.

A closer look at this diagram shows also an interesting consequence of this strategy. In effect, if we group together all relevant distinctions for which we use the same response or practice, then we end up with a partition of the set P. Figure 4.3 shows this new arrangement of elements in P.

Now, because each subset of P is constituted by relevant distinctions (i.e., perturbations) that are not distinguishable in terms of their corresponding responses, the complexity of the situation (i.e., the number of elements of the partition of P) is just six, which is more than matched by the individual's complexity (i.e., the number of practices at hand), which is eight (Fig. 4.3). Not only have we regained a balance of complexities but it is apparent that there are two unused practices.

Although the approach we have used to explain the management of complexity in a situation has been quite abstract, it is useful to illustrate a strategy to deal with this kind of complexity imbalance. This strategy suggests two actions to regain a balance of complexity. First, redesign practices in such a way that each one can take care of several relevant perturbations. Secondly, classify these perturbations to reduce the complexity of the situation. The outcome of the first action is called amplification (of individual complexity); the outcome of the second is called attenuation (of situational complexity). In other words, though we can always manage the complexity of a situation by attenuating the situational complexity and amplifying our response capacity, these are useful strategies only if they permit us to achieve a desirable performance. But in more practical terms what are the meanings of *complexity*

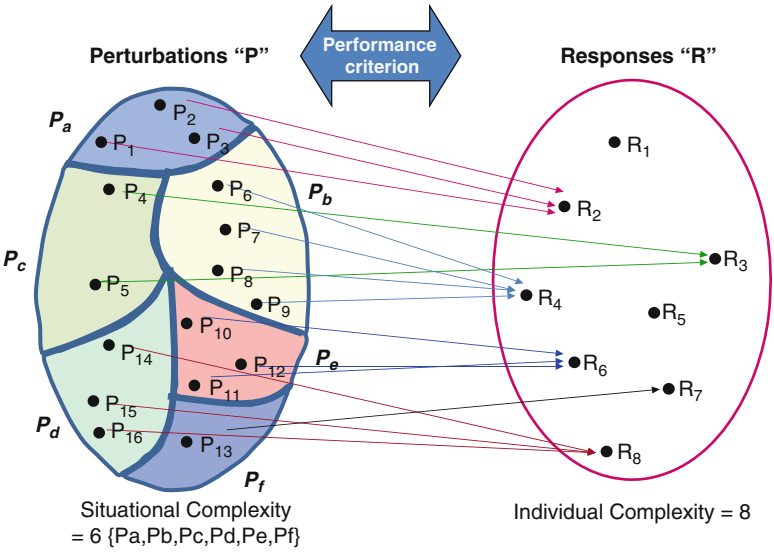

Fig. 4.3 Managing the complexity of a situation – attenuation and amplification of complexity

attenuation and *complexity amplification*? These are key concepts to understand the management of complexity and the rest of this chapter unfolds around them.

Let us start by showing a real-life example of using the idea of complexity attenuation and amplification to redesign an organizational process. In the early 1980s in Bogotá (capital of Colombia) the city's justice system had about 70 courts in charge of criminal cases. One of the crucial activities in carrying out the prosecution of those cases[1] was the 'notification'. Every major decision taken by a court had to be notified to those accused in the case. The practice of notification was considered so important that each court had people with the specific role to do it, the 'notificador'. It is this task that we analyse in terms of the management of complexity.

The purpose of this task was to notify court decisions to those accused within a time limit. These persons normally lived in Bogotá, a large city with about seven million people. A performance criterion was the number of notifications done by a court in 1 month. Typically this number was about 80, an average of 4 notifications per day or a total of about 5,600 notifications per month for all 70 courts. This was the case because every 'notificador' had to reach the personal or working address of the person to be notified. Because the size of city to notify persons living in opposite parts of the city could take several hours going for one point to the other (especially in the rush hours). Soon 'notificadores' were overwhelmed by the complexity of the task (i.e., the number of notifications waiting to be accomplished) and the courts started to accumulate cases because they could not advance them unless notifications were completed. A radical revision of this practice was needed.

The redesign of the practice was based on three ideas. First, all 'notificadores' were removed from the courts and gathered in a single notification office; secondly, the city was segmented into 70 zones, one for each 'notificador'; thirdly, every court decision was classified according to the zone in which the person to notify was living or working. Figure 4.4 shows a sketch of the new practice.

In the new practice every decision by a court was sent to the notification office. There it was classified and located in a pigeonhole. Every morning each 'notificador' took the decisions from his or her assigned place in the pigeonhole and left to the corresponding zone to do the notifications of the day. Because the size of each zone was considerably smaller than the city, performance increased considerably. Now the average number of notifications per day was about 20 per 'notificador', a total of 28,000 notifications per month for all courts. The performance of the task was multiplied by five using basically the same resources as before.

In terms of complexity management, we could see that the idea of dividing the city and classifying decisions according to this segmentation was a mechanism to attenuate the complexity of the situation (notice that in this case the *complexity driver* was the number of decisions produced by the courts). In a similar way, the idea of organizing the notification office and the assignment of a 'notificador' to a

[1]At that time in Colombia the prosecution and trailing of criminal cases was in the hands of the courts.

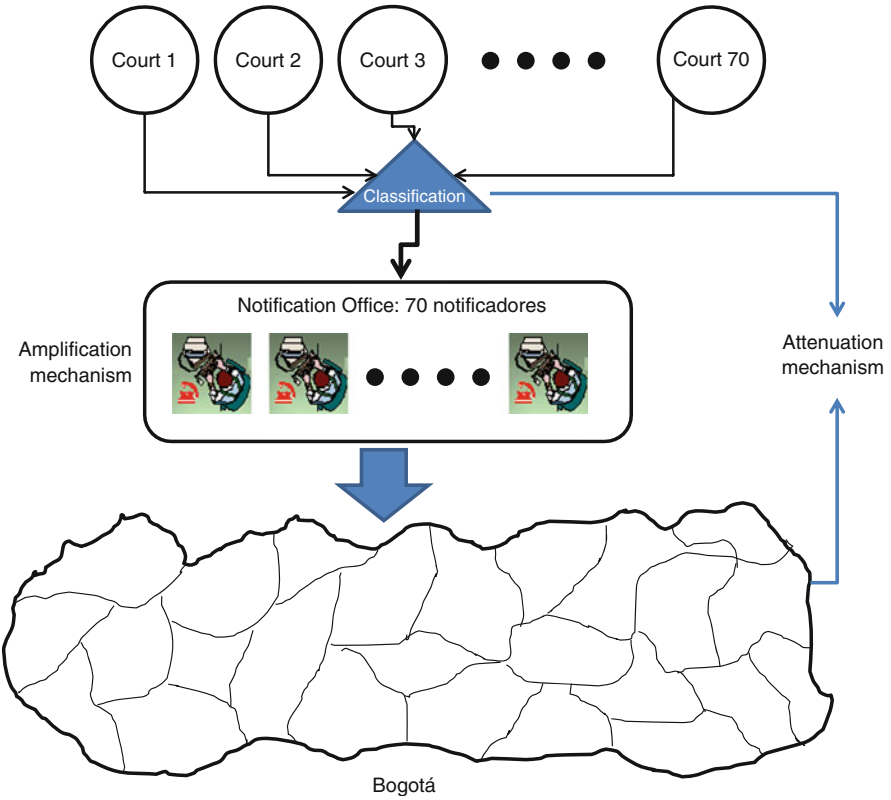

Fig. 4.4 Attenuation and amplification of complexity, the notification of criminal courts decisions

single zone was a mechanism to amplify the notification capacity of each court (now each court had the notification capacity of 70 'notificadores', not just one).

In general, we say that any device, mechanism or procedure reducing the number of states in a situation or the number of distinctions that we need to appreciate in it is an *attenuator of complexity*. So by choosing to pay attention to some aspects of the situation and not to others we are already attenuating its complexity. In fact, sheer ignorance is a huge complexity attenuator (Beer 1979). But how do we decide which factors to pay attention to in a particular situation? Well, by now it should be clear that any aspect that we experience as affecting the performance in the situation is an aspect that we have to take into account when managing its complexity. This is why purpose and performance are important to the management of complexity.

But even if we have criteria to select which aspects are relevant for the management of complexity in a particular situation, we may still make a huge number of distinctions for which we have inadequate complexity attenuators, something which impinges on our performance. In general, as we saw in the notification example, any mechanism of classification of relevant variety acts as a complexity

attenuator. This classification may be achieved by means of creating categories or imposing an order to them. For instance, the A-Z map of a big city, such as London, is a good example of a complexity attenuator. In general, it is much better than trying to locate a particular address by intuition or by asking a passerby (two alternative attenuators). In a similar way, postal codes are attenuators of complexity for the task of delivering mail across a city.

On the other hand, we say that any device, mechanism or procedure used to increase our response capacity in the situation constitutes an amplifier of complexity. Broadcasting and the organization of resources (such as the notification office) offer good ideas for designing these kinds of mechanisms. In the rest of the chapter we will present many other examples of complexity attenuators and amplifiers.

In summary, a method to manage the complexity of a situation includes the following steps: first, ascribe a purpose to the situation; second, establish performance criteria and use them to choose relevant aspects of the situation (we shall call these aspects *complexity drivers*); and third, assess, and if necessary design and implement, devices, mechanisms or procedures (in pairs) to attenuate the complexity of the situation and to amplify the response capacity. Notice that attenuators and amplifiers of complexity go in pairs as the notification example illustrates. For instance, it makes no sense to do clever distinctions if they are not used to produce or trigger appropriate actions. In fact, effective management of situational complexity depends on the balance between the set of attenuators and amplifiers we have implemented. We will go back to this point later on. By now, Fig. 4.5 illustrates the concepts we have developed so far regarding a person managing the complexity of a task in a situation.

Let us illustrate with another example the process of designing amplifiers and attenuators of complexity in a particular situation. Consider the case of a professor in

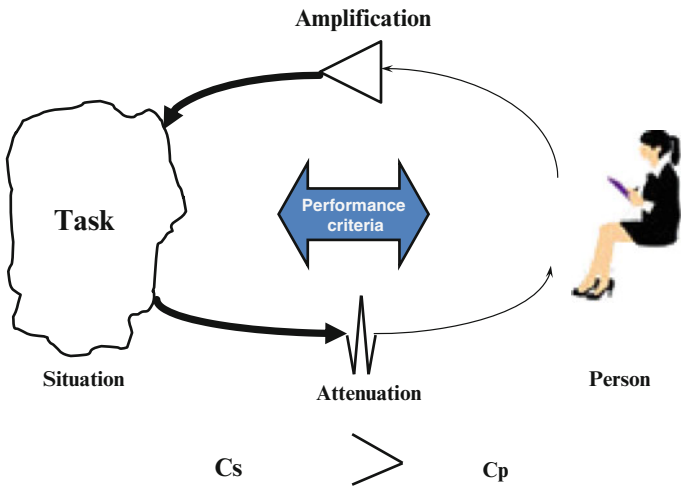

Fig. 4.5 Managing the complexity of a situation

a business school who is running a popular undergraduate course on management cybernetics. She naturally wants most of her students to understand the basic concepts of the course, so students' questions are one of the key aspects she wants to attend to in this situation; questions are an important *complexity driver* in this case.

Given that the number of questions that students may have during the course could be huge, she can set a question time schedule which will act as a complexity attenuator. For instance, she may ask students to formulate questions either during the last 10 min of each lecture or in her office, on Tuesday and Thursday, from 7 a.m. to 8 a.m. Notice that when answering the questions, in the first case the classroom acts as an amplifier of her response capacity because an answer to a specific question from a student will go to all students attending the class. In the second case, when she receives students in her office, she can use a bulletin board or an email service to make her responses available to all students or she may encourage that students talk with their classmates about their learning in these meetings. Therefore, in this way she is attenuating the complexity of the situation (by reducing the number of questions she has to deal with at a particular moment) and she is simultaneously amplifying her response capacity (by distributing each response to most or all students). Notice that making responses available to everybody may also prevent similar questions to be raised in the future; they may have been answered in advanced.

This additional example gives a flavour of the process of *designing pairs* of attenuators and amplifiers for *complexity drivers* (i.e., critical issues relevant to achieving performance criteria) in a particular situation. But there is still much more that we can say about these basic concepts of attenuation and amplification.

Suppose that our academic decides to organize the course in such a way that all students come to a general weekly lecture with her and once a week they also participate in smaller seminars run by tutors. She meets once per week with the tutors to discuss with them which aspects should be stressed during the seminars. Notice that the seminars act as attenuators of complexity from her point of view regarding the questions those students may have. The tutors will answer many of these questions during the seminars. At the same time, the tutors (and the seminars) may act as an amplifier of her response capacity whenever she decides to stress a particular point and asks tutors during their weekly meeting to do the same in the seminars.

She can also use technology to implement new attenuators and amplifiers of complexity. For instance, she may develop a web page for the course in the university's Intranet where students can post their questions at any time and she can regularly make public her answers. A 'frequently asked questions' (FAQ), chosen from her experience in previous courses, may help students deal with questions. In this case, whenever students have a question, they will go straight to the FAQ in the course's page and look for an answer. Only if they do not find an appropriate answer, they will send her the question. In this case, the course's web page acts simultaneously as an attenuator and as an amplifier of complexity. It is an attenuator because most of the questions will not reach her and it is an amplifier because she will use it to communicate her answers to all the students using a single

media. With this strategy she is, in fact, promoting that students get their answers by themselves; her concern will be in maintaining the web page updated. This is an example of a self-regulating mechanism.

Another strategy that the professor can use to manage the complexity of her course (taking the number of students' questions as a measurement of the complexity driver) is encouraging students to use a course's virtual discussion group on the web page. If she succeeds in doing this, it is quite possible that students will engage in discussing course topics and many of the questions that they have as individuals may be answered during their discussions. Notice that if this is the case, again she will be aware only of the questions that students themselves are not able to answer. In other words, by promoting the organization of students with the use of the website virtual discussion groups, only part of the questions that they have during the course will reach the professor. We call this the *residual complexity* of the situation, that is, the complexity that the academic has to deal with because it is not dealt within the situation itself (Espejo 1989). This is an example of self-organization. We will come back to this important point later on.

So far we can see that in order to manage the complexity of a situation we have the following strategies at hand: we can design pairs of attenuators and amplifiers of complexity; we can promote or enable the attenuation of complexity in the situation itself; or we can do both at the same time.

Figure 4.6 illustrates a revisited version of the strategies to manage the complexity of a situation using the academic example. We have included here self-organization and self-regulation mechanisms for attenuating the complexity inside the situation itself.

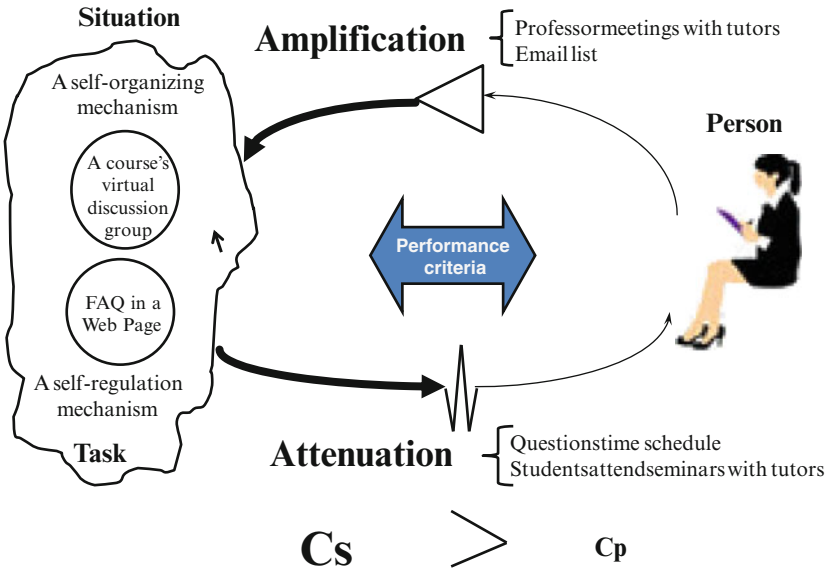

Fig. 4.6 Managing the complexity of a situation revisited

Both amplifiers and attenuators of variety are *variety operators* that may happen de facto in our daily lives or in the moment-to-moment operations of an organization, or, may be designed to make more effective the management of the situational complexity. This is what Beer has called variety engineering (Beer 1979, 1981, 1985). In methodological terms it is necessary to work out first the complexity drivers for the situation of concern; in our academic example a driver is the number of questions emerging from the professor's interactions with students. Assuming an academic situation where there are many questions, it is apparent, as was illustrated above, that multiple forms of amplification and attenuation of complexity will emerge in the practice of learning. For design purposes Figs. 4.7 and 4.8 illustrate the types of variety operators that may be useful to consider for a dynamic and effective interaction between professor and students.

For amplification it is necessary to find ways of:

- Strengthening the source variety, that is, making possible one-to-many interactions. The lecture theatre allows the professor to talk simultaneously with many students.
- Increasing the resolution of the source variety, that is, using human and technological means to unfold in more detail the source variety. A textbook, and in more general terms, a library allow students to see more variety than that provided by the professor.
- Creating new variety relevant to the regulatory situation, that is, expanding the regulatory situation beyond the professor as the sources variety. The students'

Amplifiers of a Regulator's Variety

Strengthen the source variety	Increase the resolution of the source variety	Create new variety	Make variety time independent
Professor's answers to students' questions in a lecture theatre.	Students' in-depth elaboration in an essay of the Professor's views about a particular question.	Students recognising and discussing new questions about management cybernetics, which have not been proposed by the Professor. They may use self-organizing groups for this purpose.	Publishing questions and answers in an open website, thus making them available 24 hours a day, 7 days a week.

Fig. 4.7 Four approaches for variety amplification

Variety Attenuators of an Academic Situation

Make weaker the situational variety	*Reduce resolution of the situational variety*	*Chop-off aspects of the situational variety*	Make situational variety time dependant
Select at random a handful of the students' questions for the Professor's attention.	Summarise and cluster the content of the students' questions.	Focus on questions related to particular topics at the expense of the others.	Reduce academic / students' interactions to particular periods during the course.

Fig. 4.8 Four approaches for variety attenuation

self-organization in small groups to discuss questions triggered by their interactions with the professor and tutors may generate much new variety not considered by the professor. This spontaneous generation of variety needs alignment with the professor's purposes to be a powerful amplifier of the situational variety. Otherwise it is a source of disturbances.

- Maintaining, as far as possible, the relevance of source variety over time, that is, maintaining the amplification provided by the above mechanisms throughout the length of the course.

For attenuation it is necessary to find ways of:

- Reducing, weakening, the source variety *for the regulator*. This can be achieved in the professor's case by focusing on students' *defined* variety. Asking each student to prepare and submit with anticipation questions and providing a *short time* for debating all of them in the class room reduces the source variety and possibly increases the quality of their interactions.
- Reducing the resolution of the situational variety to develop an aggregated view of a situation. This is a strategy that aggregates situational variety and reduces local resolution. This would be the case when students' questions are generic. The cost is failing to deal with individual nuances. This complexity management strategy, similar to the first one, does not restrict the source variety, which can continue to grow.
- Selecting situational variety according to criteria *defined by the professor* rather than the students. This strategy has the effect of chopping-off aspects of the

situational variety at the professor's discretion. Sorting students' questions according to the professor's experience may help to deal with the most pressing learning issues but may lose opportunities to discover hidden learning difficulties.

- Making situational variety time dependent to critical parts of the course. This strategy may help managing the professor's interactions with students over time; some parts of the course will be supported by intensive interaction, others not. The cost of this strategy may be not to keep situational variety updated over time.

Variety engineering is particularly significant today in our digital society. With the new information and communication technologies it is possible to design complexity management strategies that were unimaginable a few years ago. Variety engineering is at the core of multiple new enterprise complexity models (Espejo 2009) and is tacit to problem solving in general (Tapscott 2009; Tapscott et al. 1998). This chapter offers methodological support for this engineering.

But, beyond complexity management strategies between people and environmental situations, attenuation and amplification of complexity also takes place within people and organizations. Figure 4.9 illustrates three venues in which complexity amplification and attenuation take place: the *cognitive venue*, the *interactive venue* and the *task venue* (Espejo and Watt 1988; Whitaker 1992). Let us explain briefly each one of these venues.

The *cognitive venue* refers to the individual's capacity to create and produce some kind of cognitive order out of the situational complexity. With reference to Chap. 3, this venue relates both to the variety and the current set of practices that we have embodied for the distinctions that we have made over time in the multiple domains we have been engaged on (i.e., our individual complexity). Remember that cognition is not capacity to map environmental situations but capacity for effective action in selected domains of action; in this sense knowing is doing (Maturana and

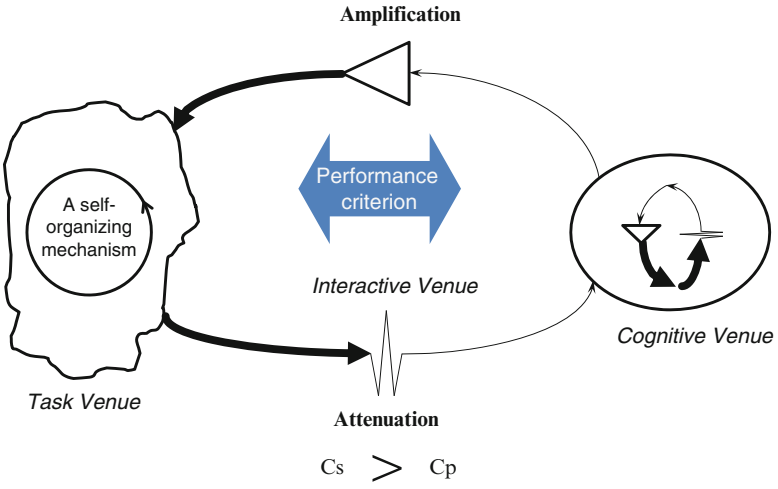

Fig. 4.9 The venues of complexity management

Varela 1992, p. 248). In this venue we develop, through learning, capacity to interact and participate in cooperative work.

Examples of complexity attenuators in the cognitive venue are listening skills, logical thought and conceptualisation (i.e., our ability to make abstractions). On the other hand, instances of complexity amplifiers in this venue are clarity of expression, creativity, systemic thinking and an ability to make a diagnostic use of concepts (Espejo et al. 1996).

The *interactive venue*, on the other hand, is that of our recurrent encounters with others. It is where we negotiate our distinctions, achieve commitments and develop mutual expectations. It is here where relationships are formed as well as self-organization and organizations unleashed. Examples of complexity attenuators in this venue are selection of relevant conversations and most fundamentally the values, norms and shared meanings underpinning our interactions. Instances of complexity amplifiers may be achieving the commitments of others and our ability to generate mutual expectations.

It is in this venue where we need to display our ability to delegate by choosing the 'right' person for a task and getting his or her commitment to carry it out. It is also in this venue where we choose to pay attention to some aspects while ignoring, at least temporary, others. Whereas in the first case we are amplifying our response capacity (through the actions of others) in the second case we are attenuating the complexity we are facing in a particular moment in time. This attenuation can be directed by exercising a personal discipline according to the following heuristics (Espejo et al. 1996): (a) deal first with those things that are important to us and that need to be done urgently; (b) decline, under most circumstances, to commit ourselves to things that may appear urgent to ourselves or to others, but upon reflection turn out to be not important in terms of our priorities, values and long term goals; (c) avoid altogether time-wasting activities that are neither important nor urgent to us; (d) use the time freed by (b) and (c) to invest as long as we can on activities that are important to us but not urgent.

In this same venue we have also to learn how to balance *local* with *distant information* and how to balance *experience* with *observation* (Espejo et al. 1996). Regarding the former let us consider two extreme situations to illustrate the point. In the first place, suppose the case of a manager of a company who is very well known by his ability to engage in communications with the people in his immediate workplace. He manages to get the commitment of colleagues and is kept very well informed on what is going on around the office. However, he does not put too much attention on what is happening outside the limits of his immediate relations. He depends mostly on others in order to have a grasp of distant information and takes little time to corroborate it from direct sources. The outcome of this may be that he will not develop an accurate understanding of relevant contexts that may affect in the near future the effectiveness of his work. It is quite common for people in those situations to be trapped in 'ivory towers' where their close colleagues filter out so much (usually unpalatable but indeed relevant) information to avoid damaging local relations. This could be a recipe for short-term success but long-term disaster.

The other extreme is the case of a manager who spends most of her time grasping and checking what is going on in her "environment" but at the expense of building relations with her immediate colleagues. She will be quite aware of distant threats and possibilities for the company's future but probably will fail in getting people's commitment to take care of necessary local actions. People around her will feel that she is out of touch with what happens in her office and she probably will not understand why, despite all her efforts the company seems to be failing in reacting fast enough to desirable changes.

These are, of course, two extreme cases but reflect the need to be aware of the importance of maintaining a balance between local communications and distant information in our interactive venues when we are engaged in the management of complexity of particular situations. Notice, finally, that this balance applies not only to situations relevant to managers of organizations but also to any role in an organization and even to most of our personal roles in daily lives. Managing local communications helps us to build up strong relations and commitments with our close mates. Being aware of what is distant for the same situations helps us in building a deeper understanding of the context in which these situations are evolving.

Regarding the emphasis in practices (e.g., experience through action) or distinctions (e.g., creativity), we say that we need to learn how to balance the two in particular situations. Let us illustrate the case by considering, again, two extreme situations. In the first, we have a person who is well known as an action-oriented person. When facing any particular issue his immediate reaction will be 'let's do something about it now!' He wants to be involved in the action and disregards discussions, debates and critical thinking as time-wasting activities. The doing is what is important to him and pragmatism is his philosophy of life. It is quite probable that a person like him will fail as a manager because he does not have the capacity to elaborate new opportunities and possibilities for his company: the 'here and now' will obscure the need to take strategic decisions for the future. The chances are that his company will get locked in its well-developed practices and niches and will fail to respond to changes in its relevant environment.

The other extreme is that of a person who, on the contrary, prefers to debate and question almost any aspect that is brought up to her attention. Her main characteristic as a manager is discussing and creating new meanings all the time. She prefers spending time developing theories and models, making more sophisticated distinctions, to understand what is going on at the expense of developing and implementing new practices. Again, her chances of success as a manager are limited; people may find it extremely difficult to work with her and feel that all those meetings, debates and discussions are effectively a waste of time: 'things simply don't happen'.

These two extremes illustrate the need of a middle-way in between as a way to balance our practical experience with our creative and reflective approach to situations of concern. In terms of the management of complexity, while the first example shows a person with little capacity to recognize and create new distinctions, the second shows a person with poor capacity to develop and implement new practices. In both cases the loops closing attenuation (making distinctions) with amplifications (developing practices) of complexity and the other way round are

wasteful. This makes apparent, furthermore, that this balance between experience and reflection is not exclusive to managers but to anyone involved in the management of complexity of relevant situations.

Finally, the *task venue* involves the more general organizational context of our interactions where we do things through others and therefore resources are not directly under our control. Complexity attenuation in this venue is directly related to self-regulation and self-organization. This is, perhaps, one of the most powerful ways of managing complexity. This is why, from the point of view of the management of complexity, it is crucial to understand how to enable self-regulating and self-organizing processes in a particular situation. Both are powerful means to deal with complex situations; potentially they reduce considerably the residual variety relevant to managers in the situation. They are means to amplify situational complexity at the same time of attenuating the complexity reaching management. We will go back to develop this concept with more detail in Chap. 6.

This discussion suggests that managing the complexity of a situation requires a balance between attenuators and amplifiers of complexity in the cognitive, interactive and task venues. Remember that, in general, to deal with residual variety each attenuator has a corresponding amplifier. For instance, in approaching a particular situation it is not enough to be skilled at building up abstract models (i.e., attenuating complexity in the cognitive venue) if we fail to make a diagnostic use of them (i.e., complexity amplifier in the same venue). We should recall here what we said in the previous chapter about complexity; in general, for the purpose of effective action, distinctions without corresponding practices are wasted distinctions.

Summarizing so far, the purposeful management of complexity in a situation implies carrying out two main actions: making explicit performance criteria; and designing and implementing pairs of attenuators and amplifiers of complexity vis-à-vis these criteria. Notice that this is a very general approach to manage the complexity of any situation similar to the ones we mentioned at the beginning of this chapter. In other words, to perform effectively in a particular domain of action we have to keep an appropriate balance between pairs of attenuators and amplifiers of complexity. But as we have said before, contrary to what intuitively we may think, this does not mean that our response capacity has to match the complexity of the situation. Only the complexity that is not absorbed by the situation itself through self-regulation and self-organization should be filtered out by appropriate attenuators and matched by our response capacity, which once properly amplified, will affect back the situation.

This is a learning mechanism that usually is adjusted as time goes by as we observe our performance in the situation. If the performance is not what is expected we may modify our sets of attenuators and amplifiers of complexity. Similarly, if we change the performance criteria probably we will have to adjust the attenuators and amplifiers of complexity again. Normally, as we mentioned in the previous chapter, more stringent performance criteria implies an increase on the number of distinctions that all those involved need to do in a situation (i.e., to increase the resolution capacity of the attenuators) and a corresponding increase in their response capacity (i.e., increase the action capacity of the amplifiers). However, it

is perfectly possible and moreover it is desirable, that ingenuity helps to bridge, in an increasingly effective fashion, the complexity gap between regulators and their relevant situations. In practice this may imply that one response is capable of dealing with a large number of distinctions.

In this learning cycle we can identify four steps as shown in Fig. 4.10.The person *observes* the situation and uses performance criteria to do an *assessment* of his or her effectiveness in the task. If the outcome is not what is expected, then they can *design* and *implement* new mechanisms to affect back the situation. If this circular process goes on, we say that the person is engaged in an individual learning loop (Espejo 2000). Notice that our capacity to observe and assess the performance in the situation (i.e., to make distinctions) is directly related to the resolution of the attenuators in place. On the other hand, the impact over the situation (i.e., the developed practices) depends on our ability to design and implement appropriate amplifiers of response capacity. Again, achieving desirable performance requires balance between attenuation and amplification of complexity.

An imbalance of complexity in any of the venues may be experienced as a break in our expectations (vis-à-vis the purpose ascribed to the task) that may need to be resolved. As we mentioned in the previous chapter, breaks in our expectations may trigger 'problem situations' or *issues of concern for us as the performers in the situation*. By referring to Figs. 4.9 and 4.10 we may identify four types of problem situations regarding these imbalances. The focus for this discussion of problem situations is on us as the performers, however, their trigger is often an inadequate *task performance*, that is, inadequate interactions of those producing the task with agents in the environment. We will come back to this point later in the chapter when

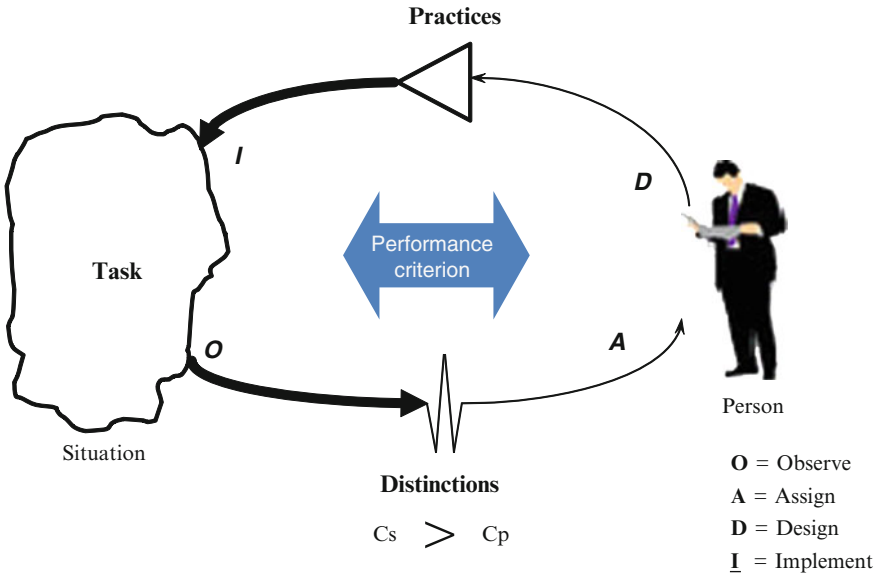

Fig. 4.10 Complexity management and individual learning

we will expand the individual management of complexity to the organizational reality.

The first types of problems are called *identity problems*. They refer to breaks in expectations triggered by a lack of clarity in the purposes and boundaries ascribed to the situation itself. This may happen when we do not explicitly ascribe a purpose to the situation or when the ascribed purpose is not aligned with the purposes ascribed by other relevant agents. Resolving these problems usually depends on the effective orchestration of *conversations for possibilities with other relevant agents,* in a context of communicative action (Habermas 1979), in order to reach aligned purposes for the situation.

These type of problems may highlight the issue of boundary judgments (Ulrich 2000). They arise in situations where it is seen as necessary to clarify the performer's task venue, in which local and distant (even unborn) stakeholders may be relevant. One common example of this situation happens when a production manager of a company is not aware of the ecological impact of his plant. This lack of awareness is tacitly showing the purpose (e.g., meaning) that he is ascribing to the task. However, if other relevant stakeholders like some of the workers in the plant and local people in the community have an increasing concern about this environmental impact, the likelihood is that an identity problem will arise sooner or later.

On the other hand, *response problems* derive from an imbalance between attenuators and amplifiers of complexity in favour of the first. In other words, the distinctions made by the individual do not have a corresponding effective response because the amplification capacity is poor. An example of this may happen if our professor invites all her students to email questions directly to her but she does not have enough time and resources to answer them.

Discrimination problems also come from an imbalance between attenuators and amplifiers of complexity but in favour of the latter. Here the individual is unable to distinguish disturbances that may be relevant for the effective management of the situation. Although amplification capacity may be enough, there is no good attenuation (i.e., the resolution of the attenuators is poor). Of course, sheer ignorance of what is relevant is the extreme case of these kind of problems and in our business course example this problem may occur if instead of leaving students to make questions freely the professor designs a form asking students to choose from a set of questions. This will act as an attenuator of the questions students can ask, however, the questions left aside could have been more important to their understanding of the course concepts, which is a performance criterion used by the professor in this situation.

Finally, *cognitive problems*[2] may occur in the cognitive venue of the performer. This is the case when individuals fail to do enough distinctions although the resolution of the attenuators (in the task and interactive venues) may be adequate, or they fail to produce effective responses although their amplifiers have enough

[2]Cognitive in this context relates to a person's capabilities for making distinctions and also acting upon them; cognition is not only a mind activity, it is a total body activity.

capacity in the interactive and task venues. An 'incompetent' professor, that is a professor whose performance is regularly underrated by their students and external reviewers, in a context in which most professors are assessed as competent, may be a simple example of a cognitive problem.

Although these four types of problems have been presented as separate items, it should be noticed that they might all be perceived in the management of complexity of a single situation. In fact, when we are performing in a situation the three venues usually intertwine; what happens in one may affect what happen in the others. Drawbacks in our cognitive venue may affect our interactive venue; drawbacks in our task venue may affect our interactive venue and so on.

It should be clear by now that managing the complexity of a situation is neither a reactive process nor a static one. It is not a reactive process because our actions may modify the situation itself. We may act now to prevent things going out of control in the future. On the other hand, it is not static because all venues are varying over time. New distinctions may be realized, new actions may be produced, new sets of attenuators and amplifiers of complexity may be designed and implemented and different criteria for performance may be set.

This dynamic, mutual interaction between us and the situation of concern is best depicted as a dance, or co-development, in which we coordinate our actions in an ongoing process of mutual adjustments. In this process of co-development we change and are changed by the situation; we are structurally coupled with it (Maturana and Varela 1992). Performing effectively in this context means maintaining stability in the situation far from equilibrium (Prigogine and Stengers 1984). Stability criteria emerge from our interactions. Whether these stability criteria are aligned with the purposes we ascribe to our actions in the situation is a complex organizational matter that we discuss in Chap. 6. For now we can say that the stability emerging from our structural couplings implies far more complexity than the performance criteria we ascribe to a situation; it implies the stability of people's interactions beyond particular measurements. Structural coupling is in the operational domain of the people involved, performance is in the informational domain of the performer and related customers.

This structural coupling is, as we mentioned before, a learning process. We learn over time, for instance, which are the aspects (i.e., distinctions) to which we must pay special attention and that need highly selective responses. They are our *critical success factors or complexity drivers* in this particular situation (Espejo et al. 1996; Rockart 1979). We will go back to this point when considering in more detail the management of complexity in the context of organizations in Chap. 6.

It is important to notice also that performance criteria relate to the individual's role in the task and not to the person. It is perfectly possible for a person to have adequate competencies for a task in a context where the assessment of the overall task's performance is not good. This would be the case of a person who knows how to improve task performance but is unable, because of contextual/structural difficulties, to steer related processes in the right direction. Therefore individual performance is the outcome of the interplay of all three complexity management venues and not of the individual's actions in isolation. These reflections imply that in

addition to problems of individual concern there are problems of organizational concern and that these two types of problems are intertwined (cf. Chap. 11).

Notice that if the professor in the example we have used in this chapter is engaged in an individual learning loop, she probably will develop new pairs of attenuators and amplifiers of complexity to increase her performance each time she runs the course. However, this may be only an individual learning if she fails to incorporate the distinctions and practices she has developed into the organizational context of the school where the course belongs to. On the other hand, if she operates in an enabling organizational environment, where courses in the school are supported by learning aids such as internet for virtual discussion groups, tutors to discuss case studies in smaller workshops, supporting colleagues and so forth, the tutor and the school will engage in an organizational learning loop. Here the balance of complexity is not only between individual academics vis-á-vis their courses but between the *role* of a professor and the courses they are in charge of. We are moving from the individual to the organizational context.

This shift is necessary because as we normally experience in our daily lives, our capacity to cope effectively with complexity is very limited. In this sense, we are often in a state of insufficient response capacity to deal with the complex situations we are facing (Espejo and Howard 1982). Organizations, in fact, enable us to perform tasks that are inherently beyond our personal capacities. But, at the same time, this implies that in this context we always rely on others to carry out the tasks for which we are accountable. This is precisely the dilemma that modern managers face all the time; they are accountable for the management of tasks that are inherently more complex than their own individual complexity. Being aware of this dilemma is what, in our view, makes relevant the discourse we have been developing so far. A popular aphorism says that variety is the spice of life, but we think we should add: 'if and only if we have requisite variety to cope with it' otherwise, life could be a nightmare. But then we have to extend the discourse on complexity management from the individual to the organizational context. This is the purpose of the rest of this chapter.

An organization co-develops with agents in its environment, such as customers, competitors, suppliers, neighbours, etc. This environment is largely beyond the knowledge and control of the people within the organization; they simply cannot take for granted the actions of the environmental agents, let alone know everything about every aspect of the world within which they operate. Similarly, managers cannot take for granted the people working within the organizational system, let alone know everything about every aspect of the organization that they manage. People may not only be unpredictable but also may defect if so they wish. However, if the organization is to maintain *viability* within its environment, and management is to steer the organization, then the Law of Requisite Variety, as we have studied in this chapter, suggests that the variety of organizational responses should at least equal the relevant challenges emerging from its environment, and also, the variety of managerial responses should at least equal the relevant challenges emerging from the organization they manage (see Fig. 4.11).

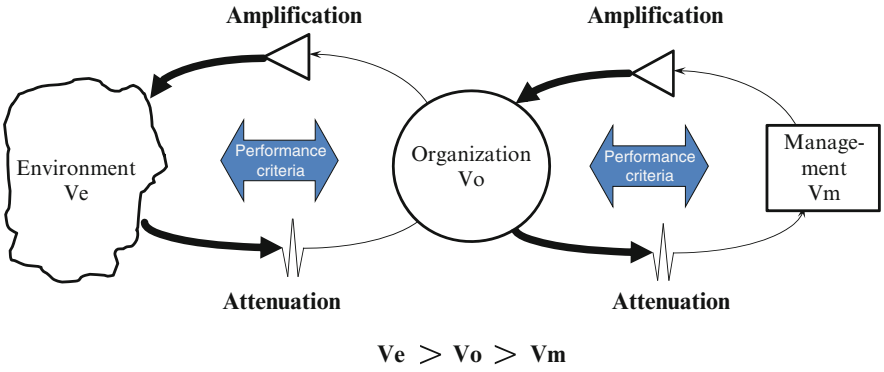

Fig. 4.11 Managing complexity in an organizational context

Yet, as established above, the variety of the environment is far larger than that of the organization, which in its turn is far larger than that of management, so, it would appear, these varieties couldn't equate. But organizations maintain viability in their environments and managements steer, more or less effectively, their organizations. Both develop one way or the other strategies to cope with the much larger variety of the opposite side.

These mismatches are resolved by recognising that of all the environmental variety, only part of it is relevant to the organization; namely that part producing the disturbances that the organization has to respond to in order to maintain viability according to the ascribed performance criteria. Also it is not necessary for people in this organization to deal with all this relevant variety since agents within the environment may perform much of this activity for the organization. For example, a car dealership network performs this service for the car manufacturer. A volume car manufacturer could not hope to deal with each individual customer buying a car; instead, the dealer sells the cars and passes on orders to the manufacturer. Thus the massive variety of the actual and prospective customers' requirements is absorbed by the dealership network, which then passes block orders to the manufacturer.

The organization as a system striving for dynamic stability in its relevant environment can only respond to a relatively small number of states in this environment, but uses agents in this environment to respond indirectly to the rest of relevant states. It is this capacity to collaborate with others and support action in the shared environment that allows the organizational system to deal with a much larger variety than otherwise would be the case. How much of the environmental variety is relevant depends on performance requirements. More competition implies higher performance requirements, which in turn increase the number of states that are relevant to the organization.

The above argument suggests that it is possible to match more variety (i.e., achieve more) with less variety (i.e., fewer resources). This implies using more of the capacities of the environmental agents in support of the organization's performance. In our example of the car manufacturer, dealers in the environment deal

with most of the relevant variety. However, the *residual variety* that is not dealt with by these environmental responses must be met by the organization itself. The orders from the car dealers to the manufacturer make up the *residual variety*, to which the manufacturer responds by producing the required number of vehicles.

The same relational pattern occurs between *management* and the other participants within the organization. To say that management controls the organization (i.e., that maintains dynamic stability with others in the organization) does not mean that the varieties of both are the same, but that the residual variety left unabsorbed by the processes of self-organization and self-regulation within the organization has to be absorbed by management. Complexity is again dealt with by the use of management amplifiers (e.g., delegation, people's commitment and training) and attenuators (e.g., exception reporting, modelling and selective conversations).

However, it is a common occurrence for amplification and attenuation processes to creep out of balance: the promises made by the sales people cannot all be fulfilled due to lack of adequate delivery channels (i.e., the attenuation of customers' requirements as expressed by accepted orders cannot be matched by delivery of products; there is not enough amplification capacity, leading to the system's underperformance), or the market segmentation in use does not offer distinctions (attenuation) that the organization's response capacity could deal with if it only knew about them; they treat varied groups of customers as if they were all the same (poor attenuation leads to waste of amplification capacity). These are instances of response and discrimination problems that arise out of imbalances between attenuation and amplification of complexity that we saw before but now we are seeing them in the organizational context.

Figure 4.12 shows this balancing of variety between the environment, the organization and its management. A test for effective management is achieving this balance at a minimum cost to the organization and management. In this figure we find that of the seven environmental critical success factors, CSFs, (the seven lines to the left of the figure) four are matched by response capacity in the environment itself (the circular arrow, which absorbs the variety of four critical

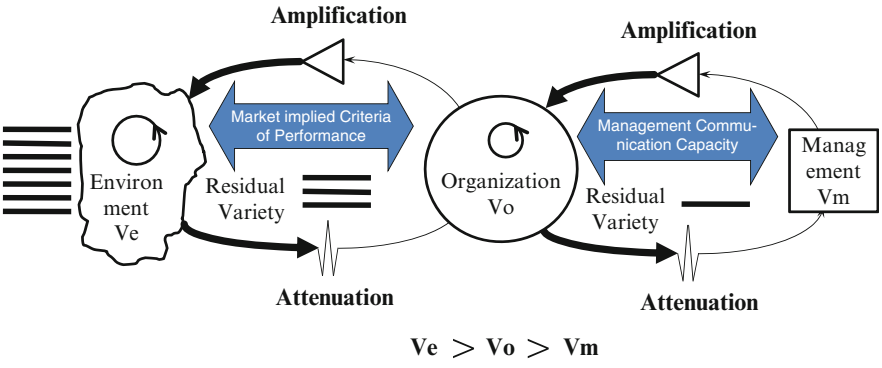

Fig. 4.12 Residual variety in an organizational context

success factors) and three by organizational responses (the three lines to the left of the organization). It is apparent that increasing the variety absorption capacity of environmental agents, to the point where say, they absorb the variety of five CSFs would make possible a leaner organization, requiring capacity to deal directly with only two CSFs rather than the three shown in the figure. The same argument applies to the interactions between management and the organization, where the more self-regulation and self-organization takes place locally within the structure the less management is required for a similar level of performance.

There is a general format that can be used to design the management of complexity either in the individual or in the organizational context according to given performance criteria. In both cases, once we have ascribed either the purpose of the task or the purpose of the organization in focus, we can identify self-regulating or self-organizing processes in the situation or in the environment respectively. For the residual variety that is left unattended by these internal mechanisms, we should design pairs of attenuators and amplifiers of complexity in order to achieve an adequate performance. Figure 4.13 shows this scheme. This Figure is a variation of Beer's homeostatic loop (Beer 1985, p. 147) that he proposed to check his four principles of organization (Beer 1979, 1985), and is the basis for his idea of variety engineering. In our version of the homeostatic loop, based on the idea of residual variety, the key for this variety engineering are the processes of self-organization and self-regulation on the high variety side, which reduce the relevant variety that the organization and management have to deal with in the environment and the

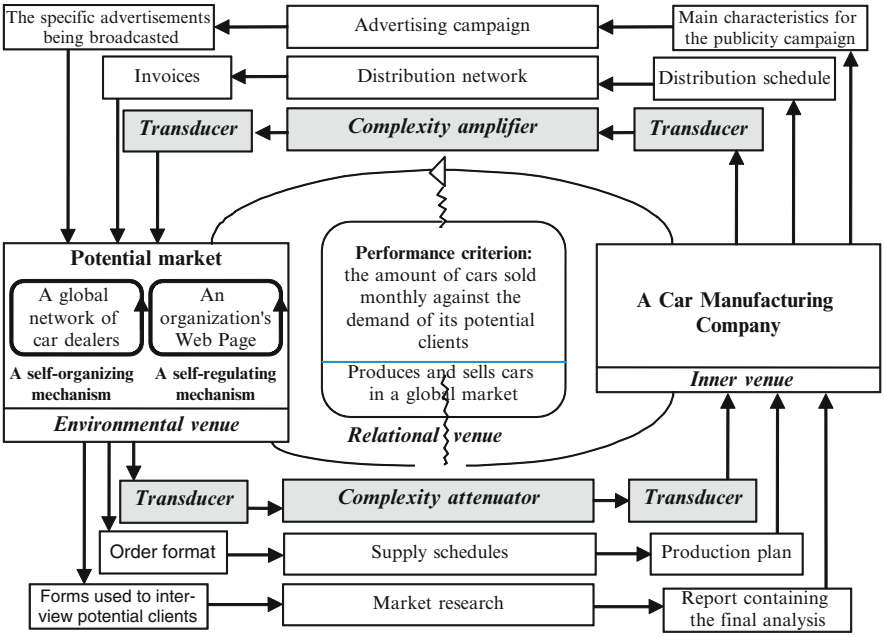

Fig. 4.13 Variety engineering (Modified from Beer 1985)

organization respectively. For these residual varieties it is necessary to work out amplifiers and attenuators of variety, as well as transducers, as proposed by Beer.

To illustrate the use of the scheme we are considering as an example the case of a car manufacturing company. Let's suppose that this company produces and sells cars in a global market. A criterion for effective performance of this company in its environment could be given by the cars sold monthly against the demand of its potential clients. Therefore demand constitutes the main complexity driver for this criterion of performance.

We could differentiate three venues related to the structural coupling of the company with its environment in the following way.[3] The *organizational processes*[4] supporting the company's production of cars constitute the *inner venue*. The relations sustained between the company with its clients and suppliers constitute the *relational venue*; and the relations taking place in the environment that have a direct effect in the complexity drivers of the company (for the established performance criteria) constitute the *environmental venue*.

As we mentioned before, a global network of car dealers manages the huge complexity of millions of potential customers and car owners in the market. This network acts as self-organizing mechanisms that attenuate the complexity in the company's *environmental venue*. Dealers are small companies on their own that are part of this environment. They are dealing with individual customers, supporting them in their purchasing activities and the maintenance of their cars afterwards. They purchase cars in large quantities and in this way they reduce the complexity that the car manufacturer has to deal with directly; the environment's residual variety is that much less challenging. These complexity operators in the environment make possible for the manufacturer to reach individual customers globally. Notice that an independent web page with a section of FAQ about cars' characteristics and performance will act in the same venue. Using it, potential customers may themselves deal with inquiries about new models, services and other relevant information regarding getting a new car. This is an example of a self-regulating mechanism.

In their turn these dealers and the manufacturing company need attenuators and amplifiers of complexity in their interactions; this is their *relational venue*. Indeed, on the one hand, dealers need to negotiate *supply schedules* (an instance of attenuators) based on their understanding of their local markets, on the other hand, the manufacturer has to set up a *distribution infrastructure* (an instance of amplifiers) to match the performance requirements implied by the negotiated schedules.

In the same venue, *market research* carried out by a specialised firm on behalf of the manufacturer is an example of a complexity attenuator that helps reducing, by classification, the multiple options of future cars expected by potential clients.

[3]These are similar to the three venues explained for the case of individual management of complexity.

[4]These are processes that allow the company to create, produce and regulate its own tasks. We will develop in more detail this concept later on in Chapter 6.

An *advertising campaign* through an appropriate agency offering the new models produced as a result of the market research acts as a corresponding amplifier of complexity (i.e., one product for multiple requests) in the same relational venue. Another example of an attenuator of complexity in this venue could be an Internet site in which, using the same software interface, multiple clients' requests are received and processed. Again, the logistics involved in the delivery of the cars sold in this way is the corresponding amplifier of complexity (i.e., the same procedures and structure is used to reach different clients' requests). Notice that attenuation does not necessarily mean chopping off environmental complexity; it may mean a more sophisticated set of distinctions that increases the enterprise's understanding of its market.

On the other hand, amplifiers and attenuators of complexity in the inner venue are related to the organizational processes of the company. We will explore them with more detail in Chap. 6.

But before finishing this chapter, there is an element in this scheme that has not been explained yet. It is the concept of a *transducer*. Conceptually, a transducer represents encoders or decoders of a message that crosses a boundary between two systems (Beer 1985, p. 53). A transducer is more than a translator in the sense that it not only translates information from one system to another, but it is a different mode of expressing the message.

The forms used to interview potential clients during the market research and the report containing the final analysis of this research are instances of transducers related to one of the attenuators of complexity mentioned in the example of the car manufacturing company (Fig. 4.11). The form is a transducer between the environment (i.e., the potential clients) and those doing the market research (i.e., the attenuator of complexity in the relational venue); the report is a transducer between this attenuator and those in the inner venue (e.g., marketing specialists in the car manufacturing company). On the other hand, a document containing the main characteristics that the publicity campaign should present to the public and the specific advertisements being broadcast are instances of transducers of the corresponding amplifier of complexity. Namely, the former is a transducer between, for example, the public relation specialists in the inner venue and the advertising company doing the campaign in the relational venue (i.e., the amplifier of complexity for the car manufacturing company) while the latter is a transducer between the advertising company amplifying the car manufacturing products and the potential customers in the environment.

Notice that so far we have assumed that there is always an imbalance of complexity between the situation and the individual or between the environment and an organization. However, this certainly may not be the case. For instance, when a new organization is formed, it has to create its market for the products or services it wants to offer.

Marketing is the natural way of producing environmental complexity but again, this has to be done in such a way that it does not overwhelm the response capacity of the organization. If this happens the organization may experience some of the response problems we mentioned before. An interesting case happened during 2005 when a new mobile company was created in a Latin American country to

exploit a new communication technology. In order to get part of the market, the newcomer started an aggressive marketing campaign offering discounts of 50% in calls per minute if made between company mobiles. The campaign was so successful that in 4 months they had taken about 40% of the market share. The company was not prepared for growing so fast and soon their communication channels collapsed, 5 months later the company was absorbed by one of its rivals. This real-life case alerts us to the importance of maintaining a balance of complexity right from the beginning.

The concepts and the method we have explained in this chapter are known as variety engineering. The management of complexity is the key concept that guides the operational design of organizations. It constitutes the building block of the viable system model as we will see in Chap. 6. But before going there, we need to formalize the concept of an organization and its difference to collectives and institutions. This is the goal of the next chapter.

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