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RESPONSES TO EXTERNALLY INDUCED INNOVATION: THEIR EFFECTS ON ORGANIZATIONAL PERFORMANCE

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Innovation may be externally induced; that is, an external threat or challenge such as the accident at the Three Mile Island (TMI) nuclear power plant sets the stage for outside parties such as the Nuclear Regulatory Commission (NRC) to propose that new practices be adopted. Managers then must make choices about how their organizations will respond. This study shows how prior performance can affect organizational responses and how these responses in turn can affect subsequent performance. Vicious cycles are shown to exist in which poorly performing organizations respond with rule-bound behavior, a response which only perpetuates their poor performance. Better-performing organizations, on the other hand, retain their autonomy, a response which reinforces their strong performance.

Innovation may arise when individuals in an organization see an opportunity that necessitates a new approach (for example, see Andrews, 1971; Child, 1972; Bourgeois, 1984). However, it also may arise when an external threat or challenge occurs that has not been anticipated. Terreberry (1968) maintains that innovation is largely a matter of external inducement, as do Downs (1967), Kelly and Kranzberg (1975), Zaltman and Duncan (1977), and others.

An example is a government requirement thrust upon firms because of an external circumstance—an accident, scandal, or financial crisis—that is beyond their control. When the survival of an organization or some program within it is threatened because of difficulties—whether they be technical, legal, or economic—it is subject to increased influence from outside forces such as government agencies, industry trade associations, financial institutions, and other parties.

This paper develops a theory of how organizations respond to externally induced innovation based on a review of the literature and findings from a study of safety review practices introduced by the Nuclear Regulatory Commission (NRC) after the Three Mile Island (TMI) accident. We argue that *less rule-bound* and *more autonomous* approaches to externally induced innovation are appropriate: as opposed to doing precisely and only as much as an external body demands, better results are likely to come from customizing what an external agent requests, or carrying out what it might require before it is necessary.

In implementing externally induced innovations, two cycles are shown to exist:

(a) a 'vicious' cycle in which poorly performing organizations respond with rule-bound behavior, a response which only perpetuates their poor performance; and
(b) a 'beneficent' cycle in which better-performing organizations have autonomy, a response which only reinforces their strong performance (see Figure 1).

The next section develops the rationale for why less rule-bound and more autonomous approaches are appropriate. The following section presents the findings from the nuclear power study,

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introducing the idea of vicious and beneficent cycles. The implications and qualifications are discussed in the concluding sections.

WHY LESS RULE-BOUND AND MORE AUTONOMOUS APPROACHES ARE APPROPRIATE

The literature is used to make four points. First, external jolts are often needed to stimulate innovation. Second, rule-bound approaches are not an appropriate response to such jolts. Third, autonomy is possible even when an organization faces extreme demands and pressures. Finally, autonomy is not only possible, but necessary and beneficial.

Jolts are needed to stimulate innovation

Jolts, both external and internal, are helpful in the innovation process. As Van de Ven (1986: 591) points out, people are programmed to 'focus on, harvest, and protect existing practices'. They therefore are likely to resist innovation. To stimulate the introduction of new programs and practices, disruptive events, which threaten the social system, are often needed (Schon, 1971).

The insight that crises, dissatisfaction, tension, and significant external stresses play an important role is common. Wilson (1963), for example, comments that organizations are unlikely to innovate unless there is a 'crisis—an extreme change of conditions for which there is no programmed response' (p. 255). Crozier writes:

> because of the resistance it must overcome, change in bureaucratic organizations is a deeply felt crisis. . . . Most analyses of the bureaucratic phenomenon refer only to the periods of routine. . . . But it is a partial image. Crisis is a distinctive and necessary element. . . . It provides the . . . means of making . . . necessary adjustments . . . [and] enabling the organization to develop (1964: 196).

Without a severe shock or jolt, people's tendency is to unconsciously adapt to slowly changing conditions. Bateson (1979) provides the following example:

> When frogs are placed into a boiling pail of water, they jump out, they don't want to boil to death. However, when frogs are placed into a cold pail of water, and the pail is placed on a stove with the heat turned very low, over time the frogs will boil to death (quoted by Van de Ven, 1986: 595).

Cyert and March (1963) argue that organizations continue with their collective routines until events require adaptation. Factors that can intervene include strong differences between expectations and aspirations, constant failure to meet objectives, and the imposition of external demands.

Meyer refers to unwelcome surprises as 'jolts', and defines them as 'transient perturbations whose occurrence is difficult to foresee and whose impacts . . are disruptive and potentially inimical' (1983: 515). Just as 'seismic tremors often disclose hidden flaws in the architecture and construction of buildings', so too environmental jolts are likely to 'trigger responses that reveal how organizations adapt to their environment' (1983: 515). Differences between expectations and aspirations and failure to meet goals can be manipulated by managers through the goal-setting process. Jolts, according to Meyer, are 'propitious opportunities for bootlegging incidental changes into organizations by camouflaging them as responses' (Meyer, 1983: 533). When they are labeled as crises, they 'infuse organizations with energy, legitimize unorthodox acts, and destabilize power structures' (p. 533).

Why rule-bound approaches are not appropriate

It is not rules *per se* that prevent creative adjustment, but the lack of alternative rules and a triggering process to activate them. If rules are narrow, circumscribed, and widely shared, they act as a defense against the perception of threat, blunting the impact of external challenges and preventing creative adjustment (Bromiley and Marcus, 1987). The appropriate internal response to a situation of external anomie is decreased reliance on existing rules and routines, and dependence on individual coping initiatives during the crisis interim.

The problem is that when unexpected events happen which create a perception of crisis, defense mechanisms are apt to emerge; and one of the strongest is a reliance on customary rules—both the explicit ones which are codified in writing and the implicit ones which are manifested in standard procedures and routines (see Janis, 1985). Starbuck and Hedberg have argued that successful organizations develop routines for dealing with recurring problems but as these routines become too well-entrenched, members of the organization tend to see situations as equivalent even if they are not. The result is that 'programs remain in use even after the situation they fit has faded away' (1977: 250), and that an organization's initial success breeds failure unless it rapidly revises its routines.

Organizational behavior is often a habitual response to familiar circumstance. Standard operating procedures seem to emerge automatically (Weick, 1979), at an 'inert' level (Leibenstein, 1976) according to well-learned 'scripts' (Langer, 1978). On the one hand these routines play a positive role in reducing uncertainty as they yield rapid reaction to similar situations and stimuli. On the other hand in the face of novel circumstances they may be radically dysfunctional. In these situations, lowered cognitive functioning and reduced responsiveness are not appropriate.

Is autonomy possible?

According to Van de Ven (1979) there is great uncertainty about the extent to which managers must succumb to external pressures and the extent to which they can maintain their autonomy. Hannan and Freeman (1977), Aldrich (1979), and McKelvy (1982) maintain that the environment is a selection mechanism that determines their current behavior and the future performance of their organizations. In the face of external pressures, managers have few meaningful choices (see also Romanelli and Tushman, 1986; according to Ashby 1956, the limiting factor is the organization's internal variety or the repertoire of responses it can generate in response to a situation). Autonomous choice is at best 'problematic', according to Aldrich (1979).

Crozier, on the other hand, maintains that managers act to preserve their autonomy, accepting dependence 'only insofar as it is a safeguard against . . . [further] submission (1964: 156). Child (1972), Bourgeois (1984), and others have emphasized the role of managerial choice in shaping domains and the characteristics of an organizations environment. Pfeffer and Salancik, for example, hold that managers are involved in a 'constant struggle' to maintain their 'autonomy and discretion' (1978: 257). To prevent losing autonomy they act to reduce external dependence. They manage external demands without necessarily satisfying them. What allows them to do so is the ambiguity of most demands (on the concept of choice within constraints, see Hrebiniak and Joyce, 1985). Equivocality gives managers choices. Scott (1987) shows that the demand for conformity is not categorical; it may apply to structure, procedures, *or* personnel but not every area. Similarly, Van de Ven and Drazin (1985) maintain that even if constraints operate at a macro-level, at a micro-level managers have substantial discretion. They have the authority to employ 'switching rules'; i.e. to apply different designs to different subunits.

Autonomy is necessary and beneficial

Having autonomy does not guarantee successful adoption. Once an idea has been adopted, transactions take place which affect how it is carried out. Many studies (see e.g. Pressman and Wildavsky, 1974; Bardach, 1977; Marcus, 1980; and Mazmanian and Sabatier, 1983) demonstrate that because actors in the implementation process have diverse interests and motivations, results often differ sharply from expectations. Thus, Mintzberg (1978) maintains that a distinction must be drawn between strategies that are *intended* and strategies that are *realized* in spite of intentions, and Whelan and Hunger (1984) show that strategies frequently are not effectively carried out because of problems that surface during implementation.

Scholars such as Lipsky (1978), Elmore (1979), Thomas (1980), Berman (1980) and Palumbo, Maynard-Moody and Wright (1983) have criticized the hierarchical view of the implementation problem. The implicit assumption in many studies (Mintzberg, 1978, is an exception) is that primary influence over policy *should be* exerted by those who formulate it, and that the implementors' role is to passively carry policy out. Discretion by implementors should be minimized. Nonetheless, there are good reasons why discretion is not only inevitable but also necessary and beneficial. It is inevitable because policy formulators often *do not have the power* to guarantee that their wishes be obeyed. It is necessary because they *do not possess appropriate information* at the level where policy is carried out. Thus in many cases policy, although constrained by policy-makers, is in essence made by the implementors. Autonomy is beneficial because it reflects greater knowledge of conditions at the point of delivery where *multiple and contradictory demands are felt*. These demands are felt in regards to objectives and tasks and in regard to conflicting legal, political, professional, and bureaucratic imperatives (Rein and Rabinowitz, 1978).

The danger, of course, is that sensitivity to 'street-level' concerns will be so great as to preclude the ability to achieve program objectives. Although policy-makers may not want to tolerate deviations from preconceived plans, the supervision and monitoring costs may be too great for them to prevent slippage. Slippage is the crux of the agency dilemma (see Mitnick and Backoff, 1984): if all controls deteriorate under the pressure of daily events, to what extent is it possible to say that policy implementors still act *for* or *on behalf of* policy formulators?

As Edwards (1980) points out, the more well-disposed implementors are toward a policy, the more likely they are to act in the formulators' interests (see also Van Meter and Van Horn, 1975). When the attitudes and perspectives of implementors differ greatly from the decision-makers, then implementation is 'infinitely more complicated' (Edwards, 1980: 89). Perrow (1983) suggests that efforts to centralize authority and control the actions of implementors (e.g. by reducing their role to passive monitoring so that they no longer have significant decisions to make) end up 'deskilling' those who carry out policy and increasing the chances of error. These efforts encourage low system comprehension, low morale, and an inability to cope with anything but the most routine conditions. Autonomy is needed to encourage a higher level of commitment and a greater level of knowledge.

Zand (1977), Gricar (1983), and others have pointed out that a key problem in the adoption of innovations is resistance. Gricar (1983) focuses on the ideological aspects of resistance (see also Sturdivant, Ginter and Sawyer, 1985), while Rogers (1972) and Zaltman and Duncan (1977) have stressed cognitive–evaluative perceptions about matters such as the innovation's technical potential, compatibility, and the support it has from influential organization members and peer groups (see also Rothman, 1974, and Schultz and Slevin, 1975). Beyer and Trice's empirical work supports the conclusion that: 'If upper management wants better performance . . . it will have to grant . . . more influence in decisions . . . directors will have to grant more autonomy to their subordinates' (1978: 264). Simon's (1969) discussion of managing decision premises, Bower's (1970) of managing the structural context, and Van de Ven's (1986) of managing part–whole relationships all suggest that autonomy, if appropriately managed, is an important factor in organizational success.

In this paper we argue that, when faced with extreme external pressures such as those that arise when an innovation is induced after a crisis, there is likely to be a relationship between the degree of autonomy managers retain and performance: i.e. *the more that managers exercise choice within a situation of constraints, the better the outcomes will be*. The difference between our work and the work of Beyer and Trice (1978) is that we concentrate on an ultimate performance measure (i.e. does the implementation of an innovation make a difference with regard to safety), while Beyer and Trice (1978) concentrate on adoption (i.e. will a proposed idea be carried out).

THE NUCLEAR POWER STUDY

The innovation examined here was introduced by the Nuclear Regulatory Commission (NRC) after the Three Mile Island (TMI) accident. It affected the management of nuclear power plant safety review systems, which came under increasing scrutiny because of allegations that managers at the TMI nuclear power plant had not learned lessons from events that had occurred at other nuclear power plants. If they had learned these lessons, it was alleged, the TMI accident would not have occurred; if it did occur, it would have been less severe (Rogovin, 1979). To remedy this situation the NRC proposed that all *newly licensed* power plants should have an Independent Safety Engineering Group (ISEG) to monitor events at a plant and at other plants, to learn the appropriate lessons, and to implement prevention strategies.

Background on TMI

The TMI accident, one of the most severe in industrial history, was thoroughly studied by the Nuclear Regulatory Commission, industry, public interest lobbyists, and academics. Some of this work is clearly pessimistic about the prospects for nuclear power. Ford (1981), for example, finds inertia and unwillingness to change in the nuclear industry. Perrow (1983) suggests that accidents are inevitable, and that little can be done to prevent them. Many analysts (Perrow, 1983, differs) have attributed what went wrong to human error (Egan, 1982). Apparently, as a result of repeated assurances that the technology was safe, there was a 'mindset' that the equipment was infallible and a preoccupation with the technical aspects of nuclear power as opposed to the human dimensions (Sills, Wolf and Shelanski, 1982). Institutional and organization inadequacies are said to have contributed as much to the accident as mechanical breakdowns.

Even before TMI, there was concern about an increase in the number of unsafe events. Reported to the NRC in the form of 'license event reports' (LERs), these are NRC's main method for assessing safety. Occurrence of events had outpaced growth in the number of new nuclear power plants, escalating from about 90 per year in 1970 to more than 3000 per year in the late 1970s (Del Sesto, 1982). The ISEG was intended to come to grips with this problem. Not sought by the nuclear power industry nor by the utilities, it had been thrust upon them by NRC because of the unfortunate TMI accident.

The idea for the ISEG was developed by the NRC in revised standard technical specifications. It is unique in *three* ways. First, there is a *focus on events and their prevention*—i.e. on examining events at a plant and at other similar plants which might indicate areas for improving safety. Second, the NRC proposed for the first time that newly licensed nuclear power plants have a *full-time* safety review staff. Third, the NRC proposed that this staff be *independent from nuclear power production*. The five full-time engineers would be on site reporting to someone off site not in the chain of command for power production. The ISEG was an expensive addition, as five full-time engineers could cost a nuclear power plant more than a half million dollars annually. As even NRC inspectors lose their objectivity over time because of their relative isolation, the unique aspect may have been the effort to develop an objective, internal watch-dog.

Methods

In studying the impact of ISEG, qualitative and quantitative methods were used. Document analysis and open-ended interviews generated the information needed to construct a typology of nuclear power plant responses. Quantitative methods were then employed to determine if these responses, as categorized, affected nuclear power plant safety. The quantitative data thus complemented the qualitative data and facilitated its interpretation.

Qualitative analysis

The documentary record. In regulating nuclear power, the NRC establishes *standard* technical specifications; individual plants are then allowed to *customize* these requirements in technical specifications which *the NRC must approve*. In 1981 there were 72 licensed nuclear power plants in the United States. Administrative sections of the technical specifications of 24 of these plants were compared with the administrative section in the standard technical specifications. The six plants licensed after TMI were chosen for scrutiny as were 18 other randomly selected plants.

Open-ended interviews. Through the mediation of the NRC, interviews were conducted at 13 of the 24 plants whose technical specifications had been examined. These plants were located in the eastern, midwestern, and southern parts of the United States. The utility systems to which they belonged differed in their structure, size, and profitability. Although this sample was not entirely random (it includes the six plants licensed after TMI), it is fairly typical of what can be found in the nuclear power industry.

Three days were spent at most facilities, with visits to both the corporate office and the plant sites. To assure objectivity, interviews were conducted by a team that included the author and at least one person with a disciplinary background different from the author's. Usually that person was an engineer with some nuclear power training. Between February and September of 1982, 80 open-ended interviews with safety review staff at 13 plants were carried out. Questions were posed about why a particular method of safety review was chosen and how this method of safety review functioned. Although the questions were standardized with their precise sequence and wording determined in advance, interviewers were encouraged to probe for additional responses and to obtain other types of feedback when appropriate.

The documentary record and the interviews were used to develop response categories. To ensure coding reliability at least three members of the research team played a role in the analysis. Early drafts were shared with safety review staff to elicit their comments. As Patton (1980) remarks, analysts can learn a great deal about the 'accurateness, fairness, and validity' of their findings from their subjects' comments.

Response categories. Rule-bound behavior was defined as adherence to externally induced frameworks; it meant complying with the standard technical specifications. Autonomy was defined as deviation from these external frameworks; it meant customization of a plant's technical specifications. The interview information was used to corroborate whether the technical documents reflected actual practice.

Two responses were classified as rule-bound behavior and four as autonomy (see Table 1). Those classified as rule-bound behavior were:

1. conformity, i.e. literal compliance with an external mandate; and
2. incremental adjustment, i.e. minor alterations or adjustments.

Two plants had an ISEG exactly as NRC proposed. This response was classified as '*conformity*'. Plants licensed prior to TMI did not have to have an ISEG or ISEG equivalent. For these plants, rule-bound behavior meant doing what the NRC expected and little more. To the extent that they modified their behavior after TMI they created subcommittees as appendages to their part-time safety groups (two plants) or added a single full-time safety review position (one plant). Thus the response of these plants was called '*incremental adjustment*' (see Lindblom, 1959 and Quinn, 1980).

Responses classified as autonomy were:

1. modification, i.e. developing and applying a new concept;
2. combination, i.e. placing the five full-time engineers in an existing function (quality assurance);
3. planning, i.e. carrying out studies and partially implementing a plan of before it was required; and
4. anticipation, i.e. acting on a plant's initiative to implement the concept before it was obligatory.

Two plants, licensed after TMI, were in the process of creating a corporate nuclear safety review department with responsibility for both off-site review and on-site safety engineering. The head of this department had vice-president status and reported directly to the president of the company. Because these alterations were an attempt to achieve NRC's intent through different means, this response was called '*modification*'.

Another response was to combine the existing quality assurance function with safety engineering. Two plants simply added the five full-time safety engineers to their existing quality assurance staff. Doing so altered the nature of what NRC intended. The distinction NRC was trying to

Table 1. Implementation responses after Three-Mile Island (TMI)

	Licensed after TMI[a]	Licensed prior to TMI[b]
Rule-bound behavior	*Conformity*: ISEG (2)	*Incremental adjustment*: subcommittees, full-time person (3)
Autonomy	*Modification*: Nuclear safety department (2) *Combination*: Quality Assurance (2)	*Planning*: technical support function (2) *Anticipation*: ISEG-like group (2)

[a] ISEG or ISEG-like equivalent required.
[b] ISEG or ISEG-like equivalent not required.
Number of plants pursuing these responses in parentheses.

make was between the 'policeman' role that quality assurance traditionally performed and the ability *to challenge* existing procedures which the ISEG was supposed to carry out. Because these plants united these functions, this response was called '*combination*'.

Plants licensed before TMI also expressed autonomy in two ways. Significant planned and actual alterations of safety review systems, when they were *not* required, suggested that these plants were acting on their *own* initiative in response to what they believed to be the lessons of TMI. Two of them planned for adoption, taking comprehensive steps to consider what they might do. They did detailed studies that would have created an entirely different type of safety review system. The proposed technical support group would have aided existing review groups as well as having responsibilities of its own. Partial staffing had started even though implementation was not obligatory. Full staffing would take place only if ISEG or an ISEG equivalent were mandated. This response, therefore, was called '*planning*'.

A different approach was to create an ISEG-like group, which was the equivalent of what NRC proposed, because management believed that such a group was necessary. To the extent that these two plants complied with NRC's proposal they did so voluntarily in a proactive manner and not because of NRC pressure or fear of NRC disapproval. This response was called '*anticipation*'

Plants that conformed and plants that anticipated—a comparison. While full advantage cannot be taken of the qualitative analysis (because of its length; see Battelle, 1983), a revealing comparison, summarizing some of the major differences between conforming and anticipating plants, can be made. At the plants which conformed, ISEG was in the parking lot and group members had to obtain 'visitors' badges' before entering. The staff interviewed maintained that ISEG's role had not been well-defined. The group did not fit in with existing practices and was not likely to have an impact. While the group made many recommendations, the recommendations generally were not accepted or implemented. The plant manager at one of the plants pointed to a huge stack of papers on a chair in the corner of his office and said 'Do you know how many of these [recommendations] we have acted on?' Showing a space of about a quarter of an inch between his thumb and forefinger, he answered, 'That much'.

In contrast, at plants that anticipated, the safety review managers maintained that ISEG was fitting in well and was having an important impact. Members of the group were reported to have had 'years of operating experience', and to be able to understand plant personnel, appreciate 'what was possible', and 'put in perspective' whether something was 'significant'. Their recommendations, both formal and informal, were accepted and 'promptly' carried out.

The structure of the ISEG at these plants was similar. The major difference was in the dispositions of the implementors. Not surprisingly, relinquishing freedom and control to the NRC after TMI resulted in resistance, while independently tailoring a response to conditions at a plant yielded an increased understanding and acceptance.

Quantitative analysis

Performance indicators. Thus, autonomy appeared to encourage a higher level of commitment, while rule-bound behavior appeared to blunt the impact of the external challenge (TMI) and to prevent creative adjustment. We therefore considered it likely that safety performance at autonomous plants would be better than performance at rule-bound plants. The primary measure of safety performance that we used was *the number of LERs or unsafe events*. A subset of LERs was also examined: events attributable to *human error*, which account for anywhere from a third to a quarter of the total number of LERs; and *significant events*, which mean that a safety-related system has been non-operational and that a plant has been shut down.

The limitations of using LERs include a tendency on the part of some plants to report events more readily than others, and different amounts of on-line time which can affect a system's susceptibility to events. Because of these limitations, other performance measures were examined. NRC regularly assesses nuclear power plant *management capabilities* based on various criteria. If the NRC gives the plant a rating of '1', it means that management attention and involvement have been 'aggressive'. A rating of '2' means that management attention and involvement are 'adequate', and a rating of '3' that 'weaknesses are evident'. While these criteria may be less prone to manipulation by plant managers then LERs, they are highly subjective inasmuch as they depend on the impressions formed by NRC staff during site visits. We therefore relied primarily on the LERs, and used the management ratings in a supplementary fashion.

Capacity ratings. These show the percentage of electric power that a nuclear power plant generates in a particular period in comparison with the amount that it could have generated based on its overall capacity—they were also examined. Downtime is expensive in a capital-intensive industry such as nuclear power, and capacity factors are critical to a utility's financial performance. This indicator was very important to nuclear power plant managers and some even had instruments on their desks which provided them with up-to-the-minute reports of their progress.

For our purposes this indicator had significance for two reasons. First, a plant may have had fewer events because it was shut down for a particularly long period of time; this could happen because of technical problems or it could be the result of a reduced demand for power. If plants had been shut down for a long period, it would show up in low capacity ratings.

The second reason for examining capacity factors is that variations in the number of events may occur because of trade-offs that nuclear power managers have made between different performance goals. Conflict among competing performance goals has been noted by many scholars including Cyert and March (1963), Dill (1965), Miles and Cameron (1982), and Sonnenfeld (1982). Safety can be jeopardized to increase productive efficiency, or productive efficiency can be sacrificed for the sake of safety. If safety had been sacrificed it would show up in a high capacity factor combined with a low safety rating.

Outcomes. We found that the plants labeled autonomous outperformed plants labeled rule-bound with respect to every performance indicator (see Table 2). The smallest difference was in the capacity ratings, which suggests that reduced operational time was not the reason for the safety differences. This finding also suggests that productive efficiency was not being sacrificed for the sake of safety, nor was safety being jeopardized for the sake of productive efficiency (at least in our sample for the time period under consideration).

To determine if these results were statistically significant we carried out tests in which the performance characteristics were dependent variables in a series of ANOVAs with type of managerial response as the independent variables (managerial response was a dummy variable). The tests show that the differences were significant with respect to both the absolute number of events and the number of human error events (see Table 3).

Because of the small sample size we had to be selective in choosing control variables. An informal check, therefore, was first carried out to see if type of technology, reactor supplier, or overall capacity might be causing the performance differences. These variables were held constant by only choosing the eight plants in the sample which were pressurized water reactors (PWRs) manufactured by Westinghouse with net MWe capacity above 825. Four of these plants had been classified as rule-bound and four as autonomous, with the rule-bound plants averaging more than twice the number of events in 1982 (112) than the autonomous plants (48.5). We therefore concluded that the results were probably not due to differences in technology, reactor supplier, or reactor size.

Instead we controlled the following factors which we suspected might be causing the performance differences:

(a) *Age*. Newer plants may have had more safety events and been less efficient because of start-up problems; or older plants may have had these difficulties because of equipment obsolescence and maintenance failures.
(b) *Size*. Larger utilities may have had the resources necessary to run safe and efficient plants; or smaller utilities may have been less bureaucratic and more flexible so they could manage their plants more safely and efficiently.
(c) *Profitability*. Profitable utilities may have been able to pay for increased safety; or less profitable ones may have had to sacrifice profitability to maintain safety.

While the F-values declined when these controls were introduced (see Table 2), the relationships

Table 2. Implementation responses and performance statistics, 1982 plant performance statistics[a]

Implementation responses	No. of cases	Average no. of events[b]	Average no. of human error events	Average no. of significant events	Average management rating	Average capacity factor
Rule-bound	5	109.2	34.0	5.0	1.9	59.6%
Autonomous	8	45.3	11.1	3.5	1.6	61.7%
Overall mean		69.8	18.6	4.0	1.7	61.0
Standard deviation		38.8	11.8	2.1	0.4	8.0

[a] Performance measures are compiled in the *1983 Nuclear Power Safety Report,* John Clewett, Washington, DC.
[b] As significant events and human error events are a subset of total events, there is a relationship between them and total events. Between human error events and total events the correlation is 0.92*, suggesting that these two items are tapping the same dimension. The correlation between sigificant events and total events, however, is only 0.52, suggesting that these two items may be tapping different dimensions.

Table 3. Implementation responses and safety: comparison of means

	Responses and the number of events[a]		Responses and the number of human error events[a]	
	Rule-bound	Autonomous	Rule-bound	Autonomous
No. of cases	5	8	5	8
Mean	109.2	45.3	34.0	11.1
Standard deviation	33.1	12.7	6.4	4.4
F-value (no controls)	21.6*		49.0*	
F-value (controlling for age, size, and profitability)	10.8*		31.5*	

[a] Run as a series of dependent variables in an ANOVA with the type of managerial response as an independent variable. Managerial response is a dummy variable.
* Significant at the 0.05 level.

between type of response and safety remained significant. These findings which show performance differences between rule-bound and autonomous responses are consistent with both the theory presented in the first section and the qualitative evidence.

Broadening the model. Still, it was possible that a potentially serious limitation of any study that uses these methods applies here: *something more fundamental* not included among the controls had caused the variations. Moreover, the relationships said nothing about the *direction of causation*: it was conceivable that a higher level of safety had produced the managerial responses rather than the opposite (i.e. the managerial responses producing a higher level of safety).

We therefore broadened the model to control for prior performance and proposed that the vicious and beneficent cycles (see Masuch, 1985) mentioned earlier (see Figure 1) would exist.

If prior performance is 'poor' (i.e. a plant is having many events), managers may feel that they have little latitude: they have to carry out NRC's edicts precisely as written. This perception may be an accurate one, for when a plant is having many events NRC is less likely to authorize exceptions from the standard technical specifications. By meeting NRC's standards there is a transference of blame which would explain rule-bound behavior (see Crozier (1964) on the perverse use of conforming to rules).

On the other hand, if prior performance is 'good' (i.e. a plant is having relatively few events), a plant is likely to enjoy substantial discretion in how it can respond, especially to a non-technical standard such as the ISEG where NRC confidence in imposing its views is not

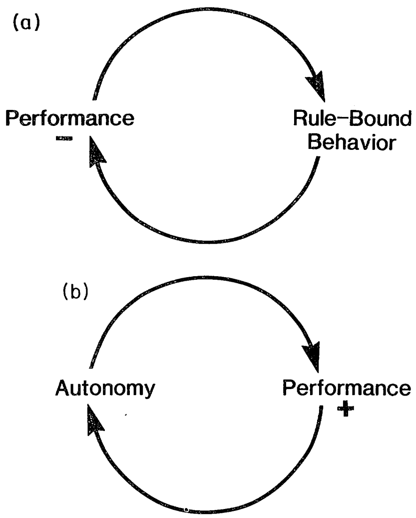

Figure 1. Vicious and beneficent cycles

likely to be great. (These are administrative standards and NRC is mainly composed of engineers.) Thus a lack of NRC restrictiveness may explain autonomy.

For the purpose of this analysis, prior performance was the number of events (LERs) in 1981, and subsequent performance was the number of events in 1982 and 1983. Earlier performance was not relevant because 1981 was the first year after TMI that newly licensed plants (six of the 13 cases in our sample) came on line. Performance in 1983 as well as 1982 was examined, because it was possible that a period of time had to elapse before new safety review arrangements moved their way through the bureaucracy and had an effect. Additional years beyond 1983 could not be used, because after 1983 the NRC liberalized its reporting requirements (plants only had to report about a third of the number of events they reported previously), and plants began to alter their safety review arrangements, modifying them in response to perceived and actual deficiencies (some of these modifications came about because of an NRC-sponsored study which was released in 1983).

The differences between rule-bound behavior and autonomy were clear throughout this period (see Table 4). Plants with rule-bound responses had nearly twice the number of events, with this difference peaking in 1982. *F*-tests confirmed that the differences were significant for each year individually and for the 3 years combined.

The innovations that we describe depict the situation that prevailed at the end of 1981, the time that we did the document analysis. During the period under investigation the situation was in flux, and the nuclear power plants that we visited had implemented in varying degrees part or all of what they intended. TMI occurred in April of 1979, and after numerous reports about the incident had been published, the NRC only established the ISEG requirement in September of 1980 (NUREG 0731). To add as many as five full-time engineers required a relatively long lead time because of well-documented shortages of skilled personnel in the nuclear power industry. Moreover, the adjustment of nuclear power plants to the post-TMI situation was long and complex because of the many other post-TMI changes the NRC required (the TMI Action Plan had over 100 items). The interviews confirmed the impression of a relatively slow adjustment.

Testing the model. To test for the effects of prior and subsequent performance, performance was viewed as a dependent and independent variable and we proposed that: implementation of a response (Ir) would be a function of performance in 1981 (P 1981) and an error term (*e*); while peformance in 1982 and 1983 (P 1982 and P 1983) would be a function of 1981 performance, the response implemented, and an error term (*e*):

$$\text{Ir} = f(\text{P }1981, e) \quad (1)$$

$$\text{P }1982 = f(\text{P }1981, \text{Ir}, e) \quad (2)$$

$$\text{P }1983 = f(\text{P }1981, \text{Ir}, e) \quad (3)$$

A discriminant analysis was necessary to test whether P 1981 affected Ir because the dependent variable was dichotomous (responses were either rule-bound or autonomous). To test Ir affected subsequent performance we ran the two regressions (2 and 3).

The purpose of running the regressions was to determine if implementation (Ir) affected performance in 1982 and 1983 (P 1982 and P 1983) controlling for prior performance (P 1981). As Granger (1969) notes, if prior values of X(Ir) are useful in predicting Y(P 1982 and P 1983), when past values of Y(P 1981) are taken into account, then X(Ir) may be viewed as a possible cause of Y(P 1982 and P 1983).

Table 4. Performance over time: differences between means

	1981		1982		1983	
Implementation response	Mean no. of events	Standard deviation	Mean no. of events	Standard deviation	Mean no. of events	Standard deviation
Rule-bound (N = 5)	92.6	26.4	109.2	33.1	98.6	28.5
Autonomy (N = 8)	49.4	16.0	45.3	12.7	56.0	23.8
Mean	66.0		69.8		72.4	
Standard deviation	29.3		38.8		32.7	
Significance of F-test	0.003		0.000		0.014	

For all three years the significance of F was 0.006.

Results. The discriminant analysis shows that prior performance correctly identifies 84.62 percent of the plant responses (see Table 5). Only two plants were incorrectly classified which *supports* the contention that prior performance had an impact on implementation.

Before presenting the regression results, the problem of multicollinearity will be addressed. As can be seen from Table 6, the correlation between the independent variables P 1981 and Ir is 0.75. While this is not unusual (given the rule of thumb that only values above 0.80 or 0.90 should be of concern; see Kennedy, 1984 and Beyer and Trice, 1978), additional checks were needed. We compared the R^2 of the independent variables regressed on each other with the R^2 of the independent variables regressed on the dependent variable (Kennedy, 1984). When P 1981 is the dependent variable and Ir is the independent variable the adjusted R^2 is 0.49. For model (2) this presents no problem—the adjusted R^2 is 0.72 (see Table 7). However, for model (3) the adjusted R^2 is 0.39, denoting a potential problem.

The third check was to enter the independent variables in the regression one by one to see if doing so substantially changed the parameter estimates or increased the variances of the already included variables (Kennedy, 1984). Separate regressions for the following functions (e is the error term in each function) were calculated:

$$\text{P 1982} = f(\text{P 1981}, e) \quad (4)$$

$$\text{P 1982} = f(\text{Ir}, e) \quad (5)$$

$$\text{P 1983} = f(\text{P 1981}, e) \quad (6)$$

$$\text{P 1983} = f(\text{Ir}, e) \quad (7)$$

The changes in parameter estimates and variances (see Table 7) show that multicollinearity was a problem for the 1983 model (3). P 1981 did not contribute to the outcome when *Ir* was in the model.

Model (2) where P 1982 was the dependent variable and Ir and P 1981 were the independent variables, however, passed the informal tests for multicollinearity (unfortunately, informal tests are all that is possible; see Kennedy, 1984). Thus, controlling for prior performance, Ir significantly affected 1982 safety outcomes as predicted.

The standardized betas allowed direct comparison of the coefficients. The effect of Ir on performance in 1982 was slightly greater (0.52) than the effect of performance in 1981 (0.42). It was also significant, while the effect of past performance was not. For 1983 the effect of prior performance (0.00) withers away in comparison with the effect of the implementation response (0.64). Along with the regression results in Table 6, which show the strong effect of Ir (in comparison with P 1981) in predicting P 1983, this provides additional evidence that the effect of the implementation responses was greater.

Discussion and implications. This analysis suggests that autonomy (defined here as constrained autonomy or approved variance from NRC's guidelines) leads to better safety performance. Poorer-performing plants had a more rule-bound response; and, as a consequence, their

Table 5. The effect of prior performance on implementation responses: a discriminant analysis

		Predicted group membership	
Actual group	No. of cases	Rule-bound	Autonomy
Rule-bound behavior	5	4 (80%)	1 (20%)
Autonomy	8	1 (12.5%)	7 (87.5%)

84.62 per cent of cases are correctly predicted.

Table 6. Correlation matrix: implementation response, prior, and subsequent performance

	Performance 1981	Performance 1982	Performance 1983
Implementation response	0.75	0.83	0.66
Performance 1981		0.84	0.50
Performance 1982			0.66

Table 7. The effect of implementation response and prior performance on subsequent performance

	Dependent variables					
Independent variables	Performance (P 1982)			Performance (P 1983)		
	P 1981 and *Ir* (2)	P 1981 (4)	*Ir* (5)	P 1981 and *Ir* (3)	P 1981 (6)	*Ir* (7)
Constant (b)	22.06	0.49	18.70	13.30	35.72	13.40
Standard deviation	(17.15)	(17.04)	(18.75)	(22.60)	(20.87)	(21.42)
t-value	1.29	0.03	1.00	0.59	1.71	0.63
Performance (P 1981)	0.55	1.06		0.02	0.55	
Standard deviation	(0.30)	(0.24)		(0.40)	(0.29)	
t-value	1.81	4.50*		0.04	1.91	
Implementation response (IR)	40.34		63.95	41.93		42.60
Standard deviation	(17.46)		(12.77)	(23.00)		(14.60)
t-value	2.31*		5.01*	1.82		2.92*
Adjusted R^2 (N = 13)	0.72	0.62	0.67	0.39	0.22	0.39

* Significant at the 0.05 level.

performance suffered. Better-performing plants, on the other hand, preserved their autonomy; as a consequence they were able to achieve a higher level of performance. These results support the idea of vicious and beneficent cycles.

This interpretation does not establish causality. For one thing the quantitative evidence is not entirely conclusive: the effects of prior performance cannot be completely separated from the effects of the implementation response. In general, a high degree of correlation, controls for underlying variables, and models which show how variables precede, follow, and influence each other are helpful in showing statistical relations based on past occurrences. However, without a theoretical base which supports the argument (Feigl, 1953), the predictive power is likely to be small.

Thus the theoretical base which we established in the first section needs to be reiterated. We argue that rule-bound approaches are not appropriate for the following reasons:

1. When a situation deteriorates, a strong perception that something has gone wrong is needed.
2. Rule-bound responses are a defense against the perception of threat, blunting the impact of external challenges and preventing creative adjustment.
3. They lead to lowered cognitive functioning and reduced responsiveness.

Autonomy, on the other hand, is appropriate because:

1. Policy formulators are not likely to possess sufficient information as the level where policy is carried out. Implementors have greater knowledge at the point of delivery where multiple and contradictory demands are felt.
2. Efforts to centralize authority and control the actions of implementors often end up deskilling those who carry out policy, and increasing the chances of error. These efforts encourage low system comprehension, low morale, and an inability to cope with anything but the most routine conditions. Autonomy encourages a higher level of commitment and a greater level of knowledge.
3. In particular, the disposition of implementors is likely to be negatively affected if they are not granted a sufficient level of autonomy, and it is their dispositions that are often critical to assuring program success.

These theoretical arguments were supported by the qualitative evidence.

After a crisis such as TMI, managers face demands for innovation that come from outside parties. They need the freedom to mold these demands in a way that will apply to the particular conditions in their organizations. If they have this freedom there is likely to be more understanding of the demands and less resistance to them. Because less rule-bound and more autonomous approaches increase internal acceptance they facilitate implementation. They are information-rich in that they take advantage of on-the-spot knowledge at the point of delivery. They therefore promote system comprehension as well as raising morale, which should lead to better results because of increased knowledge, a higher level of commitment, and a higher level of acceptance.

Kelman (1961), for example, distinguishes between the degree to which an idea is externally introduced and enforced, which he calls '*formal compliance*', and the degree to which the idea is incorporated into the behavior and expectations of people, which he calls '*identification*', and into their values and perceptions, which he calls '*internalization*'. We would argue that autonomy is needed for organizations to go beyond mere formal compliance to identification and internalization. In this respect it resembles market-driven processes which rely on individual initiative and competence to achieve objectives which cannot be accomplished by central direction. The peculiar advantage of market-like processes is their dependence on search, trial and error, and experimentation at the point of delivery where specialized knowledge and skills are needed (Schultze, 1983). A central authority simply lacks on-the-spot information to appropriately adapt a new requirement to the circumstances implementors face. If implementors have flexibility to customize external demands, compliance is likely to be with the spirit and not letter of the law, and performance is likely to be improved.

CONCLUSIONS

The full view of externally induced innovation developed here involves an event, an action taken by an external agent, a managerial response, and consequences for the organization's performance. After a stressful jolt such as TMI, an organization becomes pervious to outside influences. Managers can respond in a variety of ways. They can:

1. *combine* an external demand with existing organizational procedures and practices;
2. *modify* the demand, thereby changing the external dictate and the internal environment;
3. *anticipate* by acting on their own initiative to implement a concept before it is mandatory; or
4. *plan* by carrying out detailed studies and partially implementing their plans before they are required.

These approaches, which are likely to enhance performance, are to be contrasted with *conformity* and *incremental adjustment*, where managers take a less active role in managing external dependence.

These choices are not made in a vacuum. Prior performance affects the decisions managers take. Poor performance restricts choice. It leads to rule-bound compliance, which perpetuates weak performance. Good performance, on the other hand, opens a zone of discretion. It preserves the ability to act autonomously, which should result in continued strong performance. Thus there is evidence of a vicious cycle in which poorly performing organizations cannot escape external control, and evidence of a beneficent cycle in which strongly performing organizations have their right-to-choose protected. The implications are that managers should be aware of the possible consequences of 'blind' acceptance of external dictates, and regulators should take heed of companies that strictly obey the law. They may be doing so in 'bad faith'.

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