Prof. Dr. H.W. Volberda & Dr. G.H. van Bruggen
Faculteit Bedrijfskunde
Erasmus Universiteit Rotterdam

Environmental Turbulence: A Look into its Dimensionality

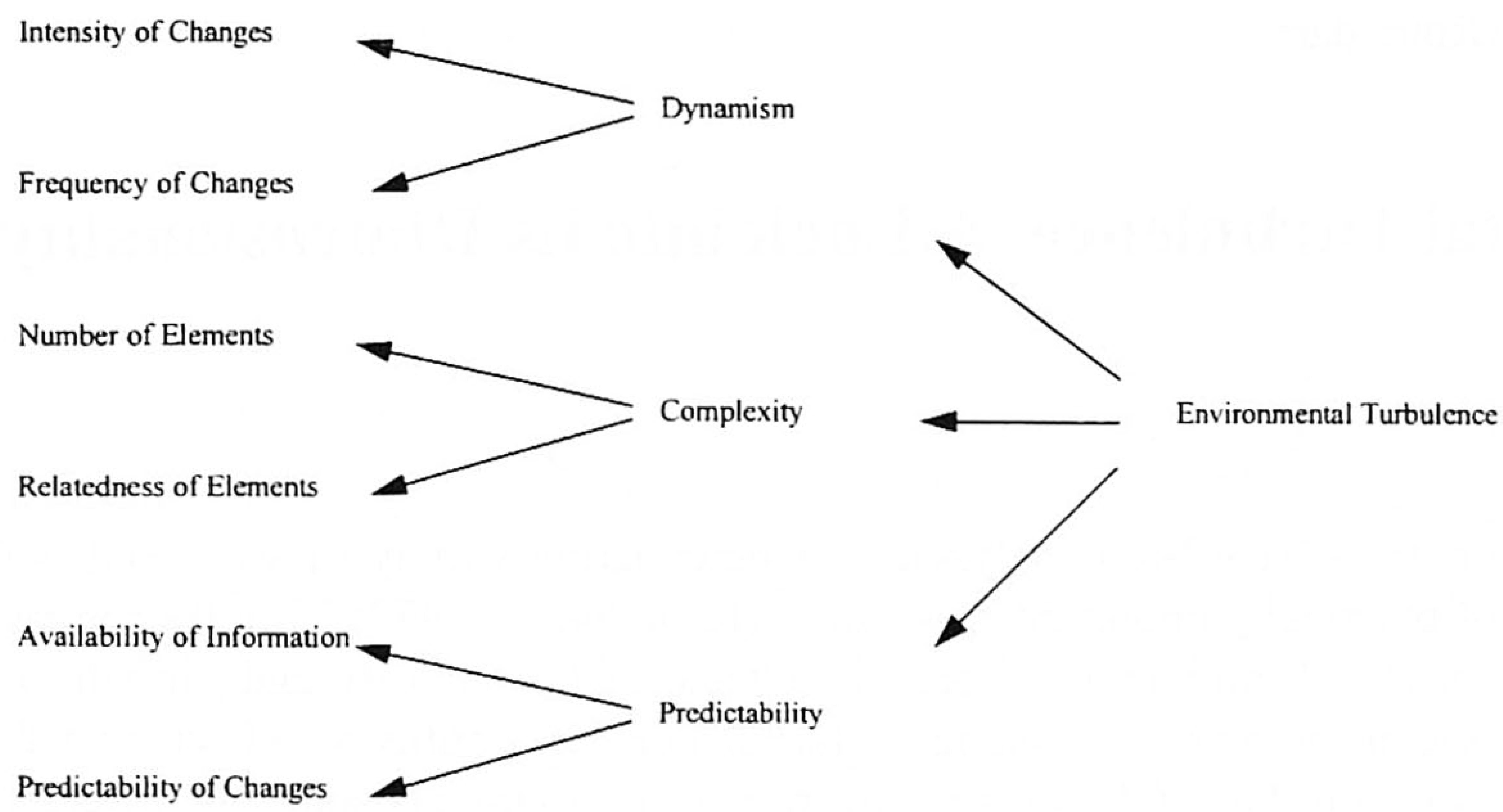
Introduction

Organizations' environments have been analyzed in a bewildering variety of ways and with respect to a number of potentially important dimensions (Khandwalla, 1977: 332). By contrast, the turbulence concept is still ambiguous. There is a great lack of clarity and virtually no agreement as to the exact meaning of environmental turbulence. The confusion reflects both the diversity of orientations in the study of organizational environments and the divergent approaches that have been developed to measure it. The aim of this paper is to develop a multi-dimensional conceptualization of environmental turbulence and to propose an instrument that measures the amount of turbulence organizations face. The measurement instrument will be tested and refined based on the results of a field survey among strategic decision-makers. The data of this survey will also permit us to gain more insight in the validity of the dimensionality of the environmental turbulence construct we propose.

Dimensions of Environmental Turbulence

According to Khandwalla (1977: 333), a turbulent environment is a dynamic, unpredictable, expanding, fluctuating environment; it is an environment in which the components are marked by change. Emery and Trist (1965) typified the turbulent environment as an environment with a high degree of interconnectedness with the organization together with a high degree of change in the environment itself. Babüroglu (1988) supports this view of increased complexity, relevant uncertainty, and dynamic and unexpected directionality of occurrences, but he especially accentuates the transitional state of turbulent environments. Likewise, the notion of continuous transition was proposed by Schön (1971), who coined the term "the loss of the stable state."
This limited discussion of environmental turbulence concepts clearly illustrates that turbulence is a complex aggregate of various dimensions related to change, and that some dimensions are more dominant than others. In many cases, unrationalized categorization of variables has resulted in dimensions of environmental turbulence that tend to overlap each other, greatly diminishing the meaning of hypothesized relations. For our purpose of assessing environmental turbulence, the dimensions dealing with static-dynamic, simple-complex, and predictable-unpredictable environments seem the most useful. At this point of theory development, these three subdimensions appear to be crucial with respect to environmental turbulence and they have the important advantage that they can be applied to all types of environments. The Ishikawa diagram in Figure 1 represents all possible configurations of these subdimensions regarding environmental turbulence. Although these three subdimensions are expected to affect environmental turbulence simultaneously, we will first consider them independently. Subsequently, we will consider their joint effects in order to develop a classification scheme for assessing the degree of environmental turbulence.

Figure 1 Subdimensions of Environmental Turbulence



Dynamism

Many researches have focused on dynamism or change as a key environmental dimension, arguing that the more variability in the components of the task environment, the more flexibility is needed within the organization (Burns and Stalker, 1961; Dill, 1958; Duncan, 1972; Thompson, 1967). In our conceptualization of environmental turbulence, this subdimension describes the degree to which elements of environmental components of the organizational unit remain basically the same over time or are in a continual process of change (cf. Duncan, 1972: 311). Consequently, this dimension can vary from *static* to *dynamic*. For instance, in a dynamic environment we may find changes in technologies, variations in customer preferences, fluctuations in product demand or a continuous withdrawal or entrance of competitors.
Nonetheless, while many investigators have considered environmental dynamism, most of them have not made a distinction between the rate of environmental change (*frequency*) and the *intensity* of the changes and have therefore implicitly equated the two. Burns and Stalker (1961), for example, focused only on the rate of change in the commercial and technical conditions the firms under investigation had to cope with. Similarly, Dill (1958) only emphasized the rapidity of shifts in the environment. However, it is possible to have fast-occurring changes in the environment with a low intensity (e.g., day-to-day fluctuations in demand), or substantial changes with a low frequency (e.g., slow decrease in demand). Therefore, in our conceptualization of environmental turbulence the dynamism dimension has two subdimensions, i.e., frequency of changes and intensity of changes.

Complexity

In addition to dynamism, theorists (Dill, 1958; Duncan, 1972, Lawrence and Lorsch, 1967; Thompson, 1967) have stressed the role of complexity of the environment. Once again, however, their studies are somewhat confusing. Most of them have only considered the numbers of elements involved in concerning a particular environmental component. The larger the number of elements involved, the more complex the environment. It seems correct to state that this subdimension of complexity corresponds to the diversity dimension mentioned by Lawrence and Lorsch (1967), Khandwalla (1977), and Mintzberg (1979), and the heterogeneity dimension mentioned by Thompson (1967) and Dill (1958). An organization which offers a broad range of special products and services, which is confronted with a broad range of clients, and which is

active in a variety of quite distinct markets and geographic areas clearly functions in a heterogeneous or diverse environment. Such an organization has to consider many elements.
Nonetheless, we agree with Lawrence (1981), in his evaluation of the Harvard Organization and Environment Program, that not only the number of elements but possibly even more important the interdependencies of these elements contribute to environmental complexity. When there are few interdependencies between the many elements of an environmental component, they can be easily divided into homogeneous groups. This is in line with Thompson's proposition (1967: 70) that organizations focusing on heterogeneous task environments seek to identify homogeneous segments. For instance, when a firm has to deal with many unrelated products or services these can be segmented into product groups, or when a firm faces different clients (industrial, consumer, governmental) they can be segmented into different client groups. In these situations, there is only little complexity. However, when there are strong relations between the many elements, segmentation is not possible anymore. In this situation, the environment is very complex. This second subdimension of environmental complexity - the relatedness of elements within environmental components - is very similar to Perrow's (1970) dimension of analyzability. To resume, the complexity of the environment depends on the number of elements within an environmental component and their relatedness.

Predictability
Finally, the (un)predictability dimension has received by far the most attention in research on organizational environments (cf. Eppink, 1978; Krijnen, 1979). Nonetheless, unpredictability, uncertainty, or unfamiliarity are usually considered as a single ultimate dimension which includes the above mentioned dimensions of dynamism and complexity (cf. Duncan, 1972; Lawrence and Lorsch, 1967). It is, however, possible to have highly dynamic and complex environments that are largely predictable. This might be, for instance, an adequate characterization of the environment of a cannery of fruit and vegetables which produces a variety of products for many related markets and faces frequent, intensive, but regular changes in supply and demand. Under such circumstances the organization does not actually face uncertainty, as managers feel reasonably confident about the sort of environmental conditions they will face in the future. In our conceptualization of environmental turbulence, therefore, unpredictability is a separate subdimension, which reflects the extent to which cause-and-effect relationships concerning environmental components are incomplete (Thompson, 1967: 85). In unpredictable environments, developments within environmental components have multiple effects that ramify in different directions and varying distances into the future.
The unpredictability dimension can range from predictable to unpredictable. When transitions (of elements) within environmental components are linear, or cyclical, or both linear and cyclical, management can extrapolate future developments. In such predictable environments, in which cause-and-effect relationships are complete, management can anticipate future developments. As an example, one might think of the seasonal demand patterns of the cannery.
Nevertheless, in many environments there is a lack of clarity of this kind of information (Lawrence and Lorsch, 1967: 27); data concerning future developments are unclear. For example, the future might show trend breaks or discontinuities, but it is unknown when these will occur and in which direction. Similarly, data regarding product-life cycles or the introduction of new products are ambiguous and the time span for definite feedback is very long. On the other hand, because of limitations of scope, management may ignore certain relevant data (Lawrence, 1981: 216). In both these situations, the environment is relatively unpredictable. Finally, some organizations function in environments in which data are simply unavailable. In such fundamentally unpredictable environments, management has to develop a high degree of

flexibility. So summarizing our discussion, we distinguish two subdimensions in the predictability dimension, i.e., predictability of changes in the environment and availability of information about changes.

Assessing Environmental Turbulence

So far, we have considered the three subdimensions of environmental turbulence separately. Needless to say, in examining environmental turbulence, all the subdimensions must be considered simultaneously. However, not every subdimension causes a similar increase of environmental turbulence. In other words, an increase of dynamism, complexity, or unpredictability certainly leads to a higher level of environmental turbulence, but not to the same extent. Therefore, it is worthwhile to investigate in an empirical study to what extent each of the three dimensions contributes to environmental turbulence as perceived by managers. Our preference for perceptual data reflects our choice to operationalize the environmental turbulence construct in terms of managerial perceptions because we think that perceptual measures are more appropriate for explaining managerial behavior than objective environmental measures (Bourgeois, 1980),
We will now describe an empirical study in which we aimed to develop an instrument to measure environmental turbulence. In this study we focused on the demand-side of the company and thus in a sense measured market turbulence. We will describe the steps we have taken to develop the measurement instrument, which we labeled as the ENVTURB scale, and the way we tried to investigate its dimensionality.

Item Selection

We generated an initial list of items related to the six dimensions (see Figure 1) from our definitions of the constructs and by reviewing the literature that relates to these six dimensions. Furthermore, exploratory interviews with management consultants and audits within Philips Semiconductors, The Dutch Postbank, and the Dutch National Gas Corporation (Volberda 1992) served as a basis for item generation. These steps resulted in a list of items. Executives from two companies assessed the content validity of each of these items. From the remaining list we selected six statements per dimension of the ENVTURB construct. The two executives, furthermore, checked whether the final statements made sense and were unambiguously worded. Based on their suggestions some parts of the questionnaire were changed and it was then finalized. Table 1 shows the 36 (7-point strongly disagree - strongly agree) items in the questionnaire we used to measure environmental turbulence. For each item we depicted the mean score and the standard deviation.

Data

Data for this study were then collected by means of sending a self-administered, structured questionnaire to 520 strategic decision-makers in Dutch organizations. The names of these managers were selected from the directory of the members of the Dutch Foundation for Strategic Management (VSB). Two weeks after the questionnaire was sent out, a written follow-up call was sent to all persons in the sample, followed by a telephone call to those managers who had still not responded. We ended up with 182 usable responses, representing a response rate of 24.6%.

Table 1 Environmental Turbulence Scale

Scale Items	Mean	(St.Dev.)	Fact.Load	(St.Err.)
Dynamism: Intensity $\rho_c = .63$				
3. Changes in our market are very intense	4.69	(1.46)	1.02	(.11)
4. Our customers regularly ask for complete new products/ services	4.21	(1.65)	1.03	(.13)
6. Our market can be characterized by more of the same (R)	3.55	(1.74)	.80	(.14)
Dynamism: Frequency $\rho_c = .76$				
7. In our market changes are taking place continuously	5.53	(1.41)	1.17	(.09)
8. Within a year nothing will have changed in our market (R)	4.97	(1.37)	.92	(.10)
9. Our supply of products/ services changes continuously	4.66	(1.55)	.89	(.11)
11. In our market the volumes of products/ services to be delivered change fast and often	3.76	(1.80)	1.02	(.13)
Complexity: Number of elements $\rho_c = .73$				
13. In making decisions in our market a lot of variables should be taken into consideration	5.47	(1.34)	1.02	(.10)
14. In our market developments are taking place which stem from all kind of directions	5.76	(1.19)	.91	(.09)
Complexity: Relatedness of elements $\rho_c = .74$				
19. In our market everything is related to everything	4.88	(1.47)	1.31	(.15)
20. A decision in our market influences a large number of factors	5.02	(1.29)	.80	(.11)
Predictability: Availability of information $\rho_c = .76$				
25. Nothing of what happens in our market will stay a secret for us	3.99	(1.65)	1.24	(.11)
26. Information we need about our market we will always get	4.33	(1.55)	1.38	(.10)
27. It is hard in this market to base decisions on reliable information (R)	2.93	(1.59)	1.00	(.11)
29. We have sufficient insight and information about who our customers are	4.83	(1.54)	.51	(.12)
30. Information about our market exists, but is not available (R)	4.11	(1.47)	.63	(.11)
Predictability: Predictability of changes $\rho_c = .64$				
31. There is a clear trend in the changes in our market	5.26	(1.17)	.67	(.13)
34. Although a lot changes in our market, it will always be possible to discover a pattern in these changes	4.86	(1.31)	.79	(.15)
35. The entrance and exit of competitors is foreseeable	4.15	(1.71)	.74	(.17)

Data Analysis

The data analysis was done following the steps of a conventional scale development procedure. We used a combination of both an exploratory and a confirmatory approach. To keep things manageable we started with performing exploratory factor analyses and reliability analyses for each of the six dimensions. Using this approach we had to remove 14 items from the original list of 36 items. This left 22 items in the scale. The remaining items each reflected one underlying construct and showed sufficiently high Cronbach alpha reliabilities. Next, a confirmatory measurement model was developed involving the 22 items measuring the six dimensions. For performing this analysis we used LISREL 8.14 for Windows. As shown in Table 2 the fit of this model (MODEL 7) was satisfying, however, it could be substantially improved by removing three items which showed either relatively low t-values or several high-standardized residuals. The measurement model (MODEL 4) of the remaining 19 items loading onto the six environmental turbulence dimensions obtained a good fit to the data (see Table 2). These results, and an examination of the pattern of residuals, seem to indicate that unidimensionality had been achieved, i.e. a single trait was underlying each of the six dimensions of environmental turbulence.

Reliability

The typical approach for the assessment of reliability is by computing Cronbach's α coefficient (Venkatraman, 1989). However, the Cronbach α coefficient assumes that items have equal reliabilities. Computing α for items with unequal reliabilities will lead to an underestimation of the reliability of the composite score (Gerbing and Anderson, 1988). We, therefore, computed composite reliabilities using the equation proposed by Werts, Linn and Koreskog (1974) which was also used by Venkatraman (1989) and does not assume equal item reliabilities within the context of confirmatory factor analysis. This reliability (ρ_c) can be computed as:

$$\rho_c = (\sum_{i=1}^{n} \lambda_i)^2 \, Variance(A) / ((\sum_{i=1}^{n} \lambda_i)^2 \, Variance(A) + \sum_{i=1}^{n} \theta_\delta)$$

where ρ_c is the composite measure reliability, n is the number of indicators, and λ_i is the factor loading which relates item i to the underlying dimension (A). According to Venkatraman (1989) when ρ_c is greater as 0.5 than the variance captured by the trait is larger than the variance captured by the error components (Bagozzi, 1981). The composite reliabilities are reported in Table 1. All values of ρ_c clearly exceed the level of 0.5, and besides for intensity of dynamism and the predictability the values even exceed the level of 0.7. However, we have to mention that only two items were measuring each of the two complexity constructs. The reliability of these scales thus must be interpreted with caution. Apparently despite of our careful pretesting procedure several of our indicators of the two dimension of complexity were not really measuring that construct.

Table 2 Model Estimation Results

Model		χ^2	df p	RMR	GFI	AGFI	NFI	TLI	CFI
1.	One General Factor	574.23	152 (<.01)	.29	.73	.66	.45	.45	.52
2.	Three Correlated Factors	274.43	149 (<.01)	.17	.87	.83	.47	.83	.86
3.	Three Correlated Factors + One Second Order Factor	Improper Solution (Negative Error Variances)							
4.	Six Correlated Factors	181.93	137 (.006)	.14	.91	.88	.83	.94	.95
5.	Six Correlated Factors + One Second Order Factor	217.04	146 (<.01)	.17	.90	.86	.79	.90	.92
6.	Six Correlated Factors + Three Second Order Factors	Improper Solution (Negative Error Variances)							
7.	Model with 22 Indicators	287.53	194 (<.01)	.17	.87	.83	.77	.89	.91
8.	Null Model	1041.64	171 (<.01)	.47	.53	.47			

Convergent Validity

Convergent validity was assessed by examining whether the factor factor loadings on the various items were significant and substantial. It appeared that all factor loadings were significant with all t-values exceeding the value of four and most of them exceeding the level of seven. Convergent validity was therefore achieved for all six dimensions of environmental turbulence. In Table 1 we present the factor loadings and their standard errors for the 19 items which measured environmental turbulence.

Discriminant Validity

Some of the dimensions of environmental turbulence were highly correlated (e.g, Table 3 shows the two dynamism dimensions especially were). Therefore, we had to determine whether these were really different constructs or indicators of the same underlying factor. To establish the discriminant validity between the dimensions we used the 19-item, six dimensional measurement model of environmental turbulence as the base model. We assessed the discriminant validity by constraining the phi-value for each pair of dimensions to one and then estimating the remaining measurement model. Since the unconstrained model gave a significantly better fit than each of the constrained models did, the dimensions thus were not perfectly correlated and discriminant validity has been achieved.

Table 3 Correlation between Environmental Turbulence Dimensions

	DYNFREQ	COMNUMEL	COMRELEL	PREDINFO	PREDCHN
Dynamism					
DYNINT	.88 (.06)	.61 (.08)	.23 (.10)	-.02 (.10)	.11 (.12)
DYNFREQ		.70 (.06)	.18 (.09)	.05 (.09)	.14 (.11)
Complexity					
COMNUMEL			.55 (.08)	-.10 (.09)	-.03 (.12)
COMRELEL				.08 (.09)	-.09 (.11)
Predictability					
PREDINFO					.23 (.10)
PREDCHN					1.00

Correlation Coefficients (Standard Errors within parentheses)

DYNINT: Intensity of Changes
DYNFREQ: Frequency of Changes
COMNUMEL: Number of Elements
COMRELEL: Relatedness of Elements
PREDINFO: Availability of Information
PREDCHN: Predictability of Changes

Relationship between the Dimensions of Environmental Turbulence

In Table 3 the correlations between the six latent variables (the dimensions of environmental turbulence) as computed by LISREL are presented. As can be seen several high and strongly significant correlations exist between the six dimensions. Especially, the correlations between each of the two dimension for dynamism, complexity and predictability are substantial. The pattern of correlations suggested some additional measurement model estimations. We will compare these models with MODEL 4 in Table 2 which is our basic measurement model consisting of six correlated dimensions.

Firstly, since several high correlations between the dimensions were present we estimated MODEL 1, which consisted of only one general factor. The fit statistics show that this model is clearly outperformed by models that allow for multiple factors. Next, since high intercorrelations existed between each of the two dimensions for dynamism, complexity and predictability, we estimated MODEL 2 with only three factors, representing each of the three dimensions. Although MODEL 2 outperforms MODEL 1, in terms of fitting the data, MODEL 4 is still doing better. Extending MODEL 2 with a second-order factor, the underlying turbulence construct, results in a MODEL 3. Estimating this model yields an improper solution because of negative error variances. Based on the results for MODEL 1 to MODEL 3 we prefer to continue with a model that contains the six dimensions. In our conceptualization of environmental turbulence we, in a sense, hypothesized the existence of higher order factors. MODEL5 suggests a second-order factor underlying the six dimensions of environmental turbulence. However, estimating this model does not yield a better fit to the data than the MODEL 4 without a higher order factor, in fact the fit statistics are even worse. Estimating MODEL 6, which contains three second order factors, one for dynamism, complexity and predictability each, again resulted in an improper solution because of improper solutions. Bagozzi (1994) already points at the difficulty of obtaining satisfactory second-order CFA model solutions. This is because the second-order CFA model makes strong demand on data. Apparently, our data do not support the very specific formulation a second-order CFA model is.

Compared to the various alternative models we estimated, the model with the six correlated dimensions, clearly performs best. One of the reasons why models with second-order factors do not show satisfactory solutions might lie in the fact that the predictability dimensions do not seem to be related to the dynamism and complexity dimensions. The two dynamism dimensions and the two complexity dimensions are strongly interrelated. These seem to be part of the environmental turbulence construct. However, based upon the perceptions of our respondents, it seems questionable whether the predictability dimension is also part of the turbulence construct. It might have been that predictability is a dimension of turbulence, however one very independent from dynamism and complexity. To check whether the amount of predictability contributes to the level of turbulence we computed correlations between the six dimensions of environmental turbulence and a single-item direct measure of environmental turbulence (i.e., our market can be characterized by a great amount of turbulence). The correlations show that the dynamism and complexity dimensions are strongly correlated with this measure. However, the correlation with the predictability dimensions is small for predictability of changes (-.08) and almost non-existent for availability of information (-0.14).

Discussion

In this paper, we have conducted an empirical study with the aim of developing a measurement instrument for assessing the level of environmental turbulence. Furthermore, the empirical study provided us with insights into the validity of our conceptualization of the dimensionality of environmental turbulence. Our results provide us with several interesting insights but also raise issues for future research.

Firstly, regarding our conceptualization our study indicates that especially the dynamism and complexity dimension are reflective of the environmental turbulence construct. According to the perceptions of our respondents, the predictability of changes is not a critical dimension of environmental turbulence. Apparently, respondents perceive turbulence mainly as changes going on. This means that, an environment is perceived as turbulent as there are changes going on in a lot of interrelated elements of this environment, even when these changes are very predictable. At the same time an environment which is characterized by only small and few changes is perceived as not turbulent, even when these changes are completely unpredictable. The difference between our conceptualization of environmental turbulence and those of our respondents raises the issue of the content validity of our conceptualization. So far we did not test for the nomological validity of our measurement instrument. A next study we have planned for such a test. We will investigate to what extent predictability is an important component of environmental turbulence which decision-makers should consider when making decisions on for example the design of their organizational form.

Our preference for perceptual data reflects our choice to operationalize the ENVTURB construct in terms of managerial perceptions because we think that perceptual measures are more appropriate for explaining managerial behavior than objective environmental measures (Bourgeois, 1980). However, these perceptions of the environment may deviate from the real environment. Therefore, in future research it would be worthwhile to identify objective measures of environmental turbulence. Relating these objective measures to our measurement instrument

will also provide us with more insight into the validity of our conceptualization of environmental turbulence.
A final point of concern is the psychometric properties of our measurement instrument. Overall, our measurement model obtained good fit statistics and we established the unidimensionality, reliability, convergent validity and discriminant validity of our measurement instrument. However, as already discussed we did not extensively test for predictive validity of our measurement instrument. We will do this in a subsequent study in which the measurement instrument will be applied in the context of a nomological network. Furthermore, unfortunately two indicators each only measure the two complexity dimensions. Although we think that the items in our measurement instrument are covering the content of the dimensions, it still would be worthwhile to develop some additional items to secure the reliability of the measurement instrument.

References

Gerbing, D. W. and J. C. Anderson, 1988. An Updated Paradigm for Scale Development Incorporating Unidimensionalityand Its Assessment. Journal of Marketing Research, Vol. XXV, (May), 186-192.
Armstrong, J. S. and T. S. Overton, 1977. Estimating Nonresponse Bias in Mail Surveys. Journal of Marketing Research, 14 (August), 396-402.
Babüroglu, O. N. 1988. The vortical environment: The fifth in the Emery-Trist levels of organizational environments. Human Relations, 41(3): 181-210.
Bagozzi, R. P. 1981. An Examination of the Validity of Two Models of Attitude. Multivariate Behavioral Research, 16, 323-359.
Bagozzi, R. P. 1994. Structural Equation Models in Marketing Research: Basic Principles. in: R.P. Bagozzi (ed.), Principles of Marketing Research, Cambridge Massachusetts: Basil Blackwell.
Bourgeois, L.J., III 1980. Strategy and environment: A conceptual integration. Academy of Management Review, 5(1): 25-39.
Burns, T., and Stalker, G. M. 1961. The management of innovation. London: Tavistock.
Dill, W. R. 1958. Environments as an influence on managerial autonomy. Administrative Science Quarterly, 2(4): 409-443.
Duncan, R. B. 1972. Characteristics of organizational environments and perceived environmental uncertainty. Administrative Science Quarterly, 17(3): 313-327.
Emery, F.E., and Trist, E. 1965. The causal texture of organizational environments. Human Relations, 18: 21-31.
Eppink, D.J. 1978. Managing the unforeseen: A study of flexibility. Ermelo: Administratief Centrum.
Khandwalla, P. N. 1977. The design of organizations. New York: Harcourt, Brace, Jovanovich.
Krijnen, H. G. 1979. The flexible firm. Long Range Planning, 12: 63-75.
Lawrence, P. R. 1981. Organization and environment perspective - the Harvard organization and environment research program. In A. H. van de Ven and W. F. Joyce (Eds.), Perspectives on organization design and behavior: 311-337. New York: John Wiley and Sons.
Lawrence, P., and Lorsch J. 1967. Organization and environment. Boston: Harvard School of Business Administration Press.
Mintzberg, H. 1979. The structuring of organizations. Englewood Cliffs: Prentice-Hall.
Perrow, C. 1970 Organizational analysis: A sociological view. London: Tavistock.
Schön, D. A. 1971. Beyond the stable state. New York: Random House.
Torgerson, W. S. 1958. Theory and methods of scaling. New York: John Wiley and Sons.
Thompson, J. D. 1967. Organizations in action. New York: Mc Graw-Hill.
Venkatraman, N. 1989. Strategic Orientation of Business Enterprise: The Construct, Dimensionality, and Measurement. Management Science, 35, 8 (August), 942-962.
Volberda, H. W. 1992. Organizational flexibility: Change and preservation - a flexibility audit and redesign method. Groningen: Wolters-Noordhoff.
Werts, C. E., R. L. Linn and K. G. Joreskog, 1974. Interclass Reliability Estimates: Testing Structural Assumptions. Educational and Psychological Measurement, 34, 25-33.