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Construct Measurement in Manufacturing Strategy Research: A Review and a Proposal

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Abstract

This paper emphasizes the need for a high degree of correspondence between the constructs underlying a theory and the method by which they are measured. This requirement is even more crucial for the field of manufacturing strategy because much previous research did not take measurement issues at the core of their investigations. However, recent studies have started to show more methodological details, and satisfy standard measurement criteria. In summary, three critical issues were identified which are related to construct measurement. They are the consistency of construct definition, using interval and multi-item scales and the significance of assessing validity.

In view of the fact that the small body of empirical studies in the field suffers from lack of methodological rigour, this paper proposes a research methodology that is based on the widely used paradigm for the development of measurement instruments formulated by Churchill (1979).

Keywords: Manufacturing strategy, Construct definition, Construct measurement, Nominal and single item scales, Validity assessment, Reliability assessment, Developing measures, Structural Equation Modelling.

Introduction

The field of manufacturing strategy does not have many, formally stated and fully developed scientific theories. Such theories, anyhow, cannot be developed in a systematic way until there is a high degree of correspondence between the constructs underlying a theory and the method by which they are measured.

Measurement issues have been emphasised much more in other related fields. As an example, Bagozzi and Philips (1982), from the marketing field, noted that ‘a failure to represent explicitly the degree of correspondence between measurements and concepts undermines the test of the theory’ (p. 459).

The important aspect of developing measures that satisfy standard measurement criteria is that it does not only lend support to the underlying theory being tested, but also helps eliminate many measures which are suspect, thus reducing the quantity of measures being proposed in the field and at the same time improving the quality and acceptability of the remaining measures. By turning again to the marketing literature, Jacoby (1978) observed that ‘more stupefying than the sheer number of our measures is the ease with which they are proposed and the uncritical manner in which they are accepted. In point of fact, most of our measures are only measures because someone says that they are, not because they have been shown to satisfy standard measurement criteria’ (p. 91).

Therefore, the purpose of this paper is to examine the application of standard measurement criteria in manufacturing strategy research and propose a methodology for construct measurement.

Measuring Strategy Constructs

A primary aim of research in the social sciences is to furnish theoretical explanations for behaviour (Gray, 1994). The means of explaining such behaviour is to develop concepts and constructs, each one concentrating and explaining one particular behaviour. The interaction of constructs, through a theoretical network, with one another therefore can reveal the effects in magnitude and direction among the constructs. Kerlinger (1986) defined 'concepts' and 'constructs' as follows: 'A concept is a word that expresses an abstraction formed by generalisation from particulars....A construct is a concept. It has the added meaning, however, of having been deliberately and consciously invented or adopted for a special scientific purpose' (pp. 26-27).

Thus according to this definition, such concepts like manufacturing strategy and manufacturing competence are constructs since they have been deliberately invented and adopted to have a particular meaning. However, empirical research dealing with such constructs has not emphasised important aspects of construct measurement. This shortcoming has been underlined in many fields of strategic management. For example, Venkatraman (1989) noted that: '.....state of attention to construct measurement in strategic management is inadequate. Researchers continue to propose and employ measures without corresponding tests for unidimensionality, reliability, convergent, discriminant and predictive validity (Venkatraman and Grant, 1986). In the absence of a systematic basis to evaluate the adequacy of measurements, confidence in research results is considerably eroded, which implies that the managerial implications derived from such results may be questionable'. (p. 944)

As for the field of operations management, Chase (1980) surveyed articles in OM journals and noted that: '...OM research is far less sophisticated in terms of alternative research designs employed than is that reported in such research journals as the Administrative Science Quarterly, the Academy of Management Journal, or the Journal of Applied Psychology' (pp. 13). Eleven years later, Swamidass (1991) observed that: 'An inspection of published field-based empirical articles by OM researchers shows that they are predominantly exploratory and use the most rudimentary form of analysis' (p. 797).

The review of empirical research in manufacturing strategy by Minor et al. (1994) and the literature review of manufacturing strategy by Dangayach and Deshmukh, (2001) further indicated that the progress of manufacturing strategy, with respect to research methodologies and measurement issues, has been slow. To overcome this lack of methodological rigour, Minor et al. (1994) suggested that future studies in manufacturing strategy should have the following characteristics:

- They must be reproducible.
- Methodological details must be described sufficiently.
- Studies must build upon previous efforts to progress the field into new grounds.

The underlying theme for the above characteristics is that there is a need for sound research methodologies to be utilised, because as Hughes et al. (1986) indicated 'Tests of substantive theory (i.e., hypothesised relationships among theoretical constructs) necessarily involve an "auxiliary measurement theory" (Blalock, 1982, p. 25) concerning relationships among theoretical constructs and their indicators. When the auxiliary measurement theory is strong, empirical analysis can lead to a greater understanding of the phenomenon under investigation. However, weak associations between theoretical constructs and observed variables may lead to incorrect inferences and misleading conclusions about relationships among the underlying theoretical constructs of interest' (p. 130).

To accommodate the need for a high degree of correspondence between constructs and their measures, scholars proposed processes for improving the reliability and validity of the scales used. Churchill (1979), for example, suggested following a paradigm that he proposed for developing better measures for constructs. Some other scholars like Bagozzi (1980) introduced more powerful statistical techniques such as structural equation modelling, at an early stage of its development, to the marketing field and from there to other branches of management. This specific technique contributed positively to the proliferation of the importance of satisfying standard measurement criteria.

Measurement issues are becoming more important in manufacturing strategy because of the numerous calls to employ empirical research which imply emphasis on quantitatively operationalised strategy constructs.

In order to improve the quality of descriptive research in manufacturing strategy, it is critical that researchers in the field reduce or eliminate the tendency to prescribe prematurely without first giving enough thought and attention to understanding the phenomenon being tested. As Mintzberg (1987) testified 'There has been a tendency to prescribe prematurely in management policy - to tell how it should be done without studying how it is done and why...Prescriptions become useful only when it is grounded in sophisticated description' (pp. 91-92).

An assessment of the empirical manufacturing strategy research reveals three distinct issues:

First, there is no consistency in the definition of constructs and no proper assessment of their dimensionality. Second, many researchers in the field have indeed employed multiple items and used interval scales in their studies. However, there are many others who utilised nominal and/ or single item scales. Therefore, the drawbacks of using nominal and/ or single item scales will be examined. Third, validity and reliability of measures have not been assessed adequately. Each of these three issues is examined below.

Inconsistency in Construct Definition

Defining a construct clearly and concisely is the first step that should be taken in order to develop better measures for that construct (Churchill, 1979). Clarity in defining a construct makes it possible for a study to be reproducible and that can facilitate for the construct to be verified and extended if needed. A cumulative body of literature can then be built because as Churchill (1979) commented 'definitions of constructs are means rather than ends in themselves. Yet the use of different definitions makes it difficult to compare and accumulate findings and thereby develop syntheses of what is known' (p. 67).

Another important advantage of having clear definitions of constructs is that it helps in choosing the dimensions of a construct and assigning measures to the dimensions (Bollen, 1989).

Leong et al. (1990), in their review of research in manufacturing strategy, examined the consistency of construct definitions in the field and concluded that 'writers in the field of manufacturing strategy have been casual about establishing their work in the context of what has been previously written. A large part of the price paid for this lack of scholarship in the field is a general inability of scholars in the field to communicate their ideas adequately. A review of the literature quickly reveals that different authors often discuss the same underlying construct but using different terminology' (p. 118). Even though the field of manufacturing strategy has developed in the last 15 years since this remark by Leong et al. (1990), the consistency of construct definitions is still a challenge that has not satisfactorily been resolved.

Employing Nominal and Single Item Scales

Researchers (e.g., Flynn et al., 1990) noted that there are four types of scales that can be utilised as shown in Table 1. Even though there were many studies that used interval scales [represented by the Likert scales] in manufacturing strategy research, there were still some that employed nominal scales.

Table 1: Types of Measurement Scales
Adapted from Flynn *et al.* (1990), p. 259

Scales	interpretation
Nominal scales	Assign observations to data (Best, 1970). For example, respondents may be asked to check the quality techniques they understood. Their choices cannot be placed in a specific order.
Ordinal scales	Indicate relative rank, or order, among the categories. For example, respondents may be asked to rank their strategic manufacturing goals. Ordinal measures have no absolute values, and the differences between adjacent ranks may not be equal.
Interval scales	Can be ranked, and the differences between the ranks are equal. The widely used Likert scale is an example of an interval scale. Interval measures may also be added or subtracted. For example, Likert scale responses are frequently added to form a summated scale. However, since a Likert scale has no true zero, responses cannot be related to each other as multiples or ratios.
Ratio scales	Have all of the properties of the three types of [scales] mentioned above, as well as a true zero and all of the qualities of real numbers. Thus, ratio [scales] can be added, subtracted, multiplied and divided. It is mostly gathered from factual, archival sources; ratio scales designed to gather opinion data are not readily available.

The disadvantages of using nominal scales are many. While these scales are adequate in the early stages of operationalising constructs, they cannot show differences within a particular group of subjects being studied. Moreover, they cannot be used in many statistical analyses which require at least an interval scale. Thus, inferences that can be made from nominal scales are very limited.

The other issue is the usage of single item scales. Because of the complexity of constructs in the social sciences, one single item cannot adequately convey the meaning of a concept (Nunnally, 1978). The reasons, as Churchill (1979) observed, are that any single item is necessarily unique which means that if it is used by itself to measure a construct then it will have low correlation with that construct. Also, single items do not individually produce reliable responses because even if a single respondent is given the chance to answer a single question twice, at two different but close points in time, it is not likely that he or she will have the exact same answer. Thus, any single item is susceptible to systematic as well as random errors which will lower its reliability and validity to capture the broader concept that is being measured.

Single item scales can be used if two assumptions are met: a construct is unidimensional, and is measured with very little error (Nunnally, 1978). However, in reality such constructs are few. The inadequacy of single item scales is vividly captured by Jacoby (1978) who complained that 'what makes us think we can use responses to single items (or even two or three items) as measures of these concepts, then relate these scores to a host of other variables, arrive at conclusions based on such an investigation, and get away with calling what we have done 'quality' research?' (p. 93).

Because of the limitations of single-item scales, multi-item scales should always be used instead. Such scales have the potential to overcome the shortcomings of single item scales. The reliability of scales is increased when the number of items is increased. Systematic and random errors associated with each single item are averaged and thus minimised for multi-item scales.

Inadequate Assessment of Validity and Reliability

Bagozzi (1980) and Bagozzi and Phillips (1982) recommended two types of analyses which must be carried out to assess the validity and reliability of measurement instrument. The first type of analysis is called internal consistency of operationalisation which refers to two kinds of tests. They are unidimensionality and reliability (Venkatraman, 1989). The purpose of unidimensionality is to assess that each item measures the theoretical construct. This test is carried out using exploratory factor analysis or confirmatory factor analysis as implemented by structural equation modelling tools such as the LISREL framework (Joreskog and Sorbom, 1978). Reliability measures the extent to which a questionnaire, summated scale or item which is repeatedly administered to the same people will yield the same results. Thus, it measures the ability to replicate the study. Cronbach's Alpha is usually used for testing the reliability of the instrument. The reliability coefficients of structural equation modelling technique can also be used.

The second category of analysis is concerned with validity. The two types of validity that are mostly conducted are convergent and discriminant validity. Convergent validity is an evaluation of the uniformity in measurement over multiple operationalisations. It can be assessed through correlation analysis, multi-trait multi-method matrix, or structural equation modelling. Discriminant validity is an assessment that the measure does not associate with another measure from which it should differ (Venkatraman, 1989). Discriminant validity is assessed with the same techniques used for examining convergent validity. If structural equation modelling is used, then discriminant validity is confirmed for any two pairs of dimensions if they are correlated and found to differ significantly from unity (Sethi and King, 1994).

The importance of assessing validity in the research process is stressed by many researchers. For example, Peter (1979, p. 6) stated that: 'Valid measurement is the sine qua non of science. In a general sense, validity refers to the degree to which instruments truly measure the constructs which they are intended to measure. If the measures used in a discipline have not been demonstrated to have a high degree of validity, that discipline is not a science'.

Part of the reason for this lack of attention towards the assessment of validity and reliability of measures is that most researchers in the field emphasise substantive relationships and implicitly think that their measures are adequate. However, this implicit assumption regarding the adequacy of their measures can seriously hamper the progress of the field.

Developing Constructs in Manufacturing Strategy Research

Leong et al (1990) in their review of manufacturing strategy observed that the field is progressing slowly due to: (1) lack of survey-based empirical work, (2) the dearth of cohesive efforts towards theory building, and (3) researchers failing to adopt ideas from the more developed and related disciplines.

With respect to the first reason regarding the scarcity of empirical studies in manufacturing strategy, Flynn et al. (1990) commented that the reasons behind it are:

- The high expenses that are usually associated with undertaking empirical studies. Financial and time resources are required for satisfactory questionnaire design and data gathering procedures.
- It is difficult to get the commitment of respondents and that can require a lot of time and persuasion.
- In the academic environment, academicians are under pressure to produce papers. The traditional methods of mathematical formulation and simulation studies are found to be faster for this purpose.
- Empirical studies have been viewed with less esteem in the field of operations management. The importance of empirical research has not been grasped.
- Many researchers are not aware of the existence of sound data collection methods and powerful statistical analysis tools.

The second reason for the slow progress of manufacturing strategy is the dearth of cohesive efforts towards theory building. This is evident from the various studies which failed to provide a consistent and clear definition of manufacturing strategy (Anderson et al., 1989). There are many other semantic differences in the literature. For example, Booz Allen and Hamilton (1982) used the term 'manufacturing mission' to denote what Skinner (1969) called, more than a decade earlier, 'the manufacturing task'. Thus the challenge for the field of manufacturing strategy as Anderson et al. (1989) commented is 'to advance the field by reducing unnecessary semantic differences, and sharpening our understanding of the potential real alternative differences' (p. 137).

The last reason identified by Leong et al (1990) as contributing to the slow advancement of manufacturing strategy is that researchers are not adopting ideas from the more developed and related disciplines. Swamidass (1989) earlier had suggested that researchers in our field should look at related fields like business strategy because 'by ignoring business strategy literature, we stand the risk of reinventing the wheel or missing out on existing concepts of potential value for the development of the manufacturing strategy area. By integrating the two literatures, manufacturing strategy can be enriched' (p. 264).

Other fields can enrich not just the content of manufacturing strategy, but also the methods we use to do research. For example, the importance of valid and reliable measures has been stressed by many researchers in various disciplines. Yet there is a lack of empirical studies in manufacturing strategy which have implemented such measures as pointed out previously.

The factors, presented above, reveal the extent of difficulties associated with empirical research. That is why there is a need to follow proven and systematic approaches in the development of construct measures and hypotheses testing.

Procedure for Developing Measures

One of the widely cited approaches for the development of measurement instruments is that provided by Churchill (1979). This paradigm has found broad acceptance in many fields of research. The paradigm consists of eight steps which are described below:

Step 1. Specifying the domain of construct:

In this step, the construct is defined constitutively and operationally. Constitutive definition means defining the boundary of the construct by delineating it from other similar constructs. Operational definition gives the construct a meaning through designating activities that will measure it.

Step 2. Generating sample of items:

In this step, dimensions of the construct and the items that associate with each dimension are derived. The derivation procedure includes literature searches and experience surveys. After the items have been identified, they are then edited. One example of editing is when dealing with a double- barrelled statement. Such statement must be split into two, or eliminated altogether. At that point, the items are included in a questionnaire, where some will be positively worded and some will be negatively worded so that tendencies to say ‘yes’ or ‘no’ on all statements are reduced.

Step 3. Collecting data:

This is the first stage of data collection. The purpose is to expose the items to further refinement as detailed in the next step.

Step 4. Purifying measures:

In this step, the items are examined empirically to verify the absence of measurement errors. This examination is called the reliability assessment. One of the tests that can be used to assess the reliability of an instrument is split-half correlation. However, the most widely used test is the internal consistency reliability using Cronbach’s Alpha. In order for the Alpha test to provide an unbiased estimate for reliability, the items must be unidimensional. Unidimensionality can be defined as the existence of one latent trait or construct underlying a set of measures (Hattie 1985; McDonald 1981). In simple terms, unidimensionality means that each item should measure only one dimension, and each dimension should measure the construct independently of other dimensions. Usually, confirmatory factor analysis is used to examine the dimensionality of a construct.

Step 5. Collecting data:

The purpose of the second data collection exercise is to cross-validate the findings from the initial data collected in step 3. This will give research some confidence that the findings from the first data collection are not due to chance.

Step 6. Assessing reliability:

In this step, the same reliability tests in the purification step have to be carried out again. Moreover, other tests like the test-retest reliability can be used.

Step 7. Assessing validity:

Reliability tests are a necessary, but not sufficient, condition for verifying the validity of the instrument. Validity in general terms means that the instrument measures what it sets out to measure (Carmines and Zeller, 1979). The validity of a construct is confirmed through convergent and discriminant validity. Convergent validity is achieved when the measure of the construct correlates highly with similar measures that are designed to measure the same construct. Discriminant validity is attained when the measure of the construct does not correlate highly with other measures that measure different constructs. Traditionally, multi-trait – multi-method matrices, proposed by Campbell and Fiske (1959) are used to assess convergent and discriminant validity. However, in recent studies in the social sciences, structural equation modelling has been applied in the process of assessing convergent and discriminant validity.

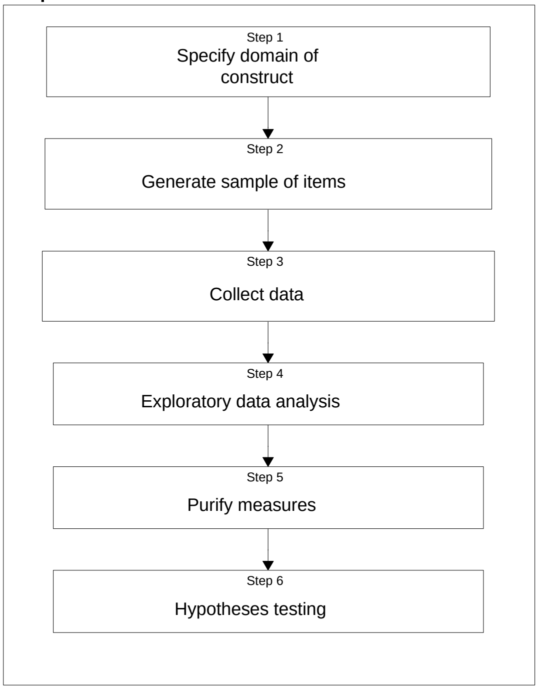
Step 8. Developing norms:

After a reliable and valid measure has been achieved, the last step is to use the raw scores as input into descriptive statistics like calculating the mean, and the standard deviation, or use the scores for inferential statistics according to the hypotheses that are being tested.

If the data is collected just once, which is the case in most empirical research efforts in the field, then Churchill's paradigm can be adapted in the following way as shown in Figure 1:

- The sample could be divided into development and validation samples which means that steps 3 and 5 are combined.
- Step 4, purifying the measures, step 6, the assessment of reliability, and step 7, the assessment of validity, can be combined into one step. This step includes both the initial purification and cross validation of the measures.
- After collecting the data and before the measures are purified, there is an important phase of data analysis which is called exploratory data analysis. This phase is included as a step in the adapted paradigm.

Figure 1: Procedure for Developing Measures
Adapted from: Churchill, 1979



Concluding Remarks

The measurement attributes of a construct, from a theoretical standpoint, are evaluated through numerous criteria. Examples of these are theoretical meaningfulness, internal and external validity, internal consistency of operationalisation, convergent validity, discriminant validity, and predictive validity (Bagozzi 1980). However, from an operational standpoint, Venkatraman (1989) suggested that, for newly developed measures, the following criteria are considered sufficient: reliability, unidimensionality, convergent validity, and discriminant validity.

The traditional method of assessing reliability and validity is to use Cronbach's Alpha, exploratory factor analysis, and bivariate correlations (Steenkamp and van Trijp, 1991), then apply path and regression analysis to find the relationships among constructs and their measures (Gregson, 1992). To test for convergent and discriminant validity, multi-trait – multi-method matrix of Campbell and Fiske (1959) is usually employed. However, research in the social sciences, in the last decade, has witnessed a move toward using a statistical technique called structural equation modelling.

Structural equation modelling (SEM), also called covariance structure analysis, is a general linear modelling technique which has its roots in factor and regression analysis. SEM is considered a confirmatory, rather than exploratory, technique. That is, a researcher will employ SEM to decide if a specific model is consistent with his or her data, rather than using SEM to find a suitable model. SEM has the following advantages:

1. It allows latent constructs to be represented by multiple measures (Martin, 1987). This is desirable in such fields as manufacturing strategy where there is a need to represent multidimensional constructs. The utilisation of multiple

indicators can contribute to the proliferation of more valid and reliable evaluations of latent constructs. In addition, utilising latent variables can permit researchers to employ a small number of exploratory constructs to explain phenomena.

2. It can assess the reliability and validity of constructs and their relationships among one another and with their measures simultaneously (Steenkamp and van Trijp, 1991).
3. It takes into account measurement errors in the models under study (Martin, 1987).
4. It can handle interval as well as ordinal data (Joreskog and Sorbom, 1989).
5. SEM has the capacity to manipulate very complex, multivariate models, especially in non-experimental research which does not have well developed techniques for testing such models that are primarily based on latent variables (Bentler, 1980). Such utilisation of SEM can lead to the enhancement of our capability to draw causal inferences.

The last advantage, in effect, sets SEM apart from other statistical techniques, Bullock et al. (1994), while assessing the relationship between SEM and causality, noted that 'although using latent variables may increase ambiguity, making causal inferences difficult, they also allow complex theories to be tested. Our world is a complex place, and, if causal evidence is ever to be effectively acquired, it will only be through designs and statistical procedures that can take such complexity into account (p. 262).

SEM has been applied quite extensively in such fields as psychology and marketing for model development, and has started to get acceptance within manufacturing strategy empirical research. We hope that this trend will continue for the better of the field.

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