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Abstract

Purpose – The purpose of this paper is to propose and empirically validates a measure of the anticipation of new technologies (ANT) construct, first suggested by Hayes and Wheelwright (1984). ANT allows establishment of a sustained competitive advantage through acquiring new technologies and the capability to use them, in advance of actual need. The theoretical foundation for ANT is developed using the literature on absorptive capacity. Several elements of supply chain management are proposed as antecedents to ANT.

Design/methodology/approach – Perceptual survey data from 317 manufacturing plants in ten countries was used to test the hypotheses using structural equation modeling and confirmatory factor analysis.

Findings – The key supply chain antecedents of ANT are supply chain planning, internal integration and supplier integration. ANT was related to both operational and cost performance.

Research limitations/implications – Potential limitations include the use of an existing database, the plant as the unit of analysis and the need to include customer integration, as well as supplier integration. The results demonstrate the competitive importance of the ANT construct and the key role that relationships with suppliers play in its development.

Practical implications – This research sheds new light on a construct whose roots are inherently practical. Suppliers and their extended networks are an important source of external knowledge about technology and future customer needs, thus, supply chain relationships are an important contributor to ANT.

Originality/value – Although the role of technology in establishing a competitive advantage has been thoroughly studied, the effectiveness of developing technologies that are expected to be important in the future has not, although this concept was first introduced almost 30 years ago. The authors use absorptive capacity to develop the role of supply chain relationships in building an organization's ANT capability, contributing to the operations strategy literature by grounding a practical construct in the theoretical literature and demonstrating its importance.

Keywords Operations strategy, Absorptive capacity, Supply chain integration, Anticipation of new technologies

Paper type Research paper

Why do investments in technology yield big dividends for some organizations, but not for others? Organizations invest in new technologies because they believe that they will be instrumental in achieving reduced costs, improved flexibility, faster customer deliveries, improved quality and other important outcomes. However, this has not been consistently found in the literature; rather, technology investments have been associated with improved performance in some cases (Kotha and Swamidas, 2000; Das and Narasimhan, 2001; Fawcett and Magnan, 2002), minor or no changes

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in performance in others (Cordero *et al.*, 2009; Cagliano and Spina, 2000) and declining performance in others (Chung and Swink, 2009).

Consider the example of two firms that produce a similar product. Company A conscientiously scans the environment for new technologies, goes to trade shows and meets with technology sales reps, in order to learn about state-of-the-art, turnkey process technology that has a proven effect on performance. However, no matter what sort of technology investments it makes, Company A never gains market share or commands a price premium. Company B, on the other hand, tinkers with its existing process technology, adapting it to meet its current needs. When considering new technology investments, it pursues multiple leads simultaneously, sometimes going down the wrong path and investing in technologies that do not ultimately work out. In learning about new technologies, it goes to the same trade shows and meets with the same sales reps as Company A, but it also talks to its suppliers to see what they know. It asks customers about their future needs, developing and investing in process technologies that might be useful in the future. It develops its workforce to use technologies that it believes will be important for future generations of its products. The result? Company B leads its market, and its processes are the standard that is benchmarked by other companies.

Why is there such a performance difference between Company A and Company B? Company A invests in the best process technology available for today's products, with impressive results. However, such technology is readily available to any competitor with sufficient funds. At best, it can only establish technology parity with its competitors, playing catch-up and scrambling to mimic what they are doing. It continues to find itself unprepared for changes in its competitive environment as new challenges unfold. Furthermore, Company A does not consider whether technology investments are aligned with its unique strategy, history, market and problems.

Company B, on the other hand, focusses on both its current products and future generations of products. It speculates about the manufacturing and process technology that will be needed to support them, drawing upon knowledge that it acquires from a wide range of sources. It filters this knowledge for alignment with its strategy and potential relevance to the problems it currently faces and that it anticipates facing in the future. It also develops its workforce for what its anticipated future technology needs are. Not surprisingly, some of the leads do not pan out, and Company B sometimes invests in technologies that are not ultimately helpful in producing its future products. However, it is well prepared for those technologies that are relevant to its future because it has mastered them in advance. If Company's B's assumptions about its future are correct, it will have a robust competitive advantage, because it is prepared for new technologies and customer needs when they emerge. Thus, Company B establishes a moving target that its competitors struggle to keep up with.

We propose that organizations with the best performance understand the importance of anticipating new technologies, thinking about changing customer needs and the technologies and capabilities that will be needed to support them in the future. Our research is based on the work of Hayes and Wheelwright (1984), who described the best organizations as constantly searching for new technologies, anticipating and preparing themselves for their implementation at some point in the future, even though there may not be an immediate need. They suggested that organizations that anticipate new technologies are better prepared to implement them when needed and to exploit them as a source of competitive advantage. Although Hayes and Wheelwright (1984) described anticipation of new technologies (ANT) as a key characteristic of world class manufacturers, this construct has not been empirically validated nor positioned in the theoretical literature.

This research focusses on two research questions. First:

RQ1. What is the relationship between ANT and competitive performance?

Second:

RQ2. How can an organization nurture its capability to anticipate new technologies?

We propose that supply chain management is important in developing this capability, because suppliers can be a potent source of ideas about technologies that may be important in the future, particularly as they work with their extended networks. We use absorptive capacity to explain the importance of supply chain management in nurturing ANT.

We begin by describing the ANT construct and articulating its key characteristics, based on Hayes and Wheelwright (1984). We draw upon the organizational theory literature on absorptive capacity to draw parallels with ANT and set the stage for describing the role that supply chain integration can potentially play in supporting ANT. Hypotheses are tested using a sample of 317 manufacturing plants in ten countries.

Literature review

ANT

Although originally introduced by Hayes and Wheelwright (1984), the ANT construct offers significant potential for organizations facing dynamic competitive environments. Hayes and Wheelwright (1984) described ANT as a distinguishing trait of world class manufacturers, whose competitive strategy is based on their manufacturing capabilities. ANT is the "extent to which an organization anticipates the new technologies that will be important to it in the future, acquires them and develops capabilities for implementing them, in advance of actual need" (Hayes and Wheelwright, 1984).

There are several key characteristics of ANT. First, ANT is based on an organization's anticipated future needs. While a well-run organization like Company A may do extensive technology development for its current products, an organization that is skilled in ANT, such as Company B, also continually invests in the process and manufacturing technologies that it believes will benefit its future generations of products (Hayes and Wheelwright, 1984; Maier and Schroeder, 2001). Thus, it must be able to anticipate what its customers' future needs will be, which future products will satisfy these needs, which new technologies will be most relevant in supporting them and which new capabilities will be needed to effectively deploy them. Thus, successful ANT requires having a good understanding of future generations of customers and products, having the resources and foresight to acquire new technologies in advance of need and developing capabilities to implement them in a way that aligns with future goals and objectives.

Second, ANT focusses on both investments in technologies and development of capabilities; thus, it has both a "hard" and "soft" side. Both are critical, because investments in technology are readily imitable by competitors with deep enough pockets; technology, alone, is "a great equalizer, eroding the competitive advantage of even well-entrenched firms and propelling others to the forefront" (Porter, 1985, p. 93).

Although an organization like Company A may seize a temporary competitive advantage by investing in state-of-the-art process and manufacturing technology:

> [...] if this [...] comes to be regarded as a goal in and of itself, if the organization does not immediately begin experimenting and tinkering with it, pushing it to do things for which it wasn't intended (but which it might eventually accommodate), the advantage is soon lost [...] Their energy spent, they watch in frustration and helplessness as their world class competitors relentlessly march past them (Hayes *et al.*, 1988, p. 25).

Thus, the combination of hard investments and tacit capabilities makes ANT difficult to imitate.

Third, ANT can be costly. It involves the development and acquisition of technologies that may or may not actually be relevant in the future, thus, substantial capital, time and other resources are required. Because some of the technologies that it had believed would be critical in the future may never actually materialize or may turn out to be unimportant to its strategy, an organizations that is less skilled in ANT may have costly false starts, wasting significant time and money. Thus, ANT can be a risky and costly strategy. However, organizations that are skilled in ANT have a significant competitive advantage because they have invested in appropriate new technologies and developed the necessary capabilities in advance of need, causing competitors like Company A to scramble to catch up. Thus, while the risks associated with ANT are significant, the potential benefits are a potent source of competitive advantage.

Relationship between ANT and absorptive capacity

Cohen and Levinthal's (1990) absorptive capacity construct provides a theoretical foundation for ANT. Absorptive capacity is the ability to acquire and assimilate knowledge and utilize it effectively, in order to achieve better performance (Robinson and Sutbberud, 2011; Jabar *et al.*, 2011; Kogut and Zander, 1993; Jansen *et al.*, 2005).

We view ANT as a specific case of absorptive capacity. While absorptive capacity focusses on knowledge, ANT focusses on a specific type of knowledge: knowledge about both hard technologies and tacit capabilities for effectively implementing them. In addition, absorptive capacity does not differentiate between knowledge relevant to current problems and knowledge that will be relevant in the future, while ANT is specifically oriented toward the future. Nonetheless, the absorptive capacity construct provides a useful framework for understanding ANT and the role that supply chain management plays in acquiring, assimilating, transforming and exploiting external knowledge to effectively anticipate new technologies. In the following sections, we describe relevant concepts from the absorptive capacity literature, then apply them to ANT.

Zahra and George (2002) described two broad categories of absorptive capacity. Potential absorptive capacity is the capability to acquire and assimilate external knowledge, while realized absorptive capacity is the capability to transform and exploit knowledge that has been acquired and assimilated.

Potential absorptive capacity. Acquisition. According to the absorptive capacity literature, acquisition is the ability to identify and acquire externally generated knowledge (Zahra and George, 2002). Determining the proper amount of acquisition is a balancing act between pursuing too many costly leads and ignoring leads that have potential; ideas and discoveries that fall beyond the search zone can be easily overlooked by an organization that is unable to relate to them (Zahra and George, 2002).

In ANT, acquisition focusses on knowledge about technologies that may be relevant in the future, including both existing technologies that may be important to future products and technologies that are still being developed. Acquisition begins with recognition of the strategic importance of being ahead of competitors in implementing new technologies, providing the impetus for scanning the external environment for new manufacturing and process technologies that may hold potential (Hayes and Wheelwright, 1984). Because technologies that have not yet been refined or developed may hold the key to future success, it is important that acquisition focusses on both traditional sources of external knowledge, such as trade shows and technology sales reps, and non-traditional sources, such as suppliers and their extended networks.

Assimilation. According to the absorptive capacity literature, assimilation consists of analyzing, processing, interpreting and developing an understanding of external knowledge (Zahra and George, 2002). Once it has been acquired, knowledge is transmitted across organizational boundaries (Liao *et al.*, 2003), where it is transformed and communicated to relevant departments and individuals. Interactions between people with diverse knowledge enhance the ability to make novel linkages and associations during this process (Cohen and Levinthal, 1990). Thus, internal networks are important for transferring knowledge between individuals and across functional departments.

The concept of assimilation applies well to ANT, whose filtering function is critical in assessing the future potential of new technologies. Rather than selecting between proven state-of-the-art alternatives, organizations address questions related to the composition of their future markets and products, uncertainties about the viability of technologies that are still under development, and the appropriateness of technologies used in current applications to future needs. Without the ability to filter potential new technologies so that it only pursues those with the greatest relevance to its future, an organization can be vulnerable to pursuing dead-end paths. Thus, ANT should be guided by the organization's strategy.

Realized absorptive capacity. While the ability to acquire and assimilate external knowledge may enable generation of a new, enlarged knowledge base, this will not necessarily lead to superior performance (Brettel *et al.*, 2011). Rather, external knowledge must be translated into products and processes. Realized absorptive capacity is the ability to leverage knowledge that has already been acquired and assimilated (Zahra and George, 2002). It is comprised of transformation and exploitation.

Transformation. Transformation is the ability to combine existing knowledge with newly acquired and assimilated knowledge (Zahra and George, 2002), adding, deleting and interpreting it. Transformation changes the character of knowledge through the combination of apparently incongruous sets of information to arrive at new insights, facilitate recognition of opportunities and alter the way an organization sees itself and its competitive landscape.

In ANT, transformation operates similarly, combining apparently incongruous sets of information, with the goal of supporting future needs. Thus, transformation includes the ability to understand potential technologies, the future environment and the problems it anticipates facing.

Exploitation. According to the absorptive capacity literature, exploitation applies knowledge to refine, extend and leverage existing competencies or create new competencies by incorporating acquired and transformed knowledge (Zahra and George, 2002). It is the ability to harvest external knowledge for commercial gain.

In terms of ANT, exploitation is the ability to apply transformed knowledge to develop and implement new technologies in a way that supports future needs. It is cumulative, so the more an organization has transferred knowledge into future commercial applications in the past, the easier it is. Thus, past history of exploiting external technology knowledge is an important component of ANT capability.

Relationship between ANT and supply chain management

We posit that supply chain management can support ANT through supply chain planning, supplier integration and internal integration. The high-level focus of supply chain planning helps in recognizing the potential need for new technologies in the future. Further, the extent to which a supply chain is externally integrated (Bowersox *et al.*, 1999; Frohlich and Westbrook, 2001; Naylor *et al.*, 1999) provides access to external sources of knowledge about technology, while internal integration provides a structure for assimilating external knowledge about new technologies.

Supply chain planning. Supply chain planning is important in developing a deep understanding of the dynamic supply chain environment, in order to develop a strategy for dealing with its challenges (Elbashir *et al.*, 2011). A forward looking perspective focusses on identifying gaps between current technology and what will be needed to support future products, markets, environment and other challenges, overseeing the transfer of technology between plants as needed and aligning the capabilities of suppliers with current and future needs. In doing so, supply chain planning focusses on suppliers as potential external sources of technology knowledge.

Internal integration. Internal integration, which is interaction and collaboration between an organization's internal functions (Kahn and Mentzer, 1998; Flynn *et al.*, 2010; Zhao *et al.*, 2011), enhances knowledge exchange across internal functions by bringing together different sources (Jansen *et al.*, 2005) to deepen knowledge flows across functional boundaries and facilitate understanding of new external knowledge. This enables employees to combine their existing and newly acquired knowledge, providing the foundation for assimilation, transformation and exploitation. Without effective internal integration, the potential of a new technology may not be recognized.

Supplier integration. A supply chain is an important external source of knowledge about potential new technologies. A strong relationship with suppliers provides fine-grained knowledge about their operations, personnel, resources (Uzzi, 1996; Bernardes, 2010), blurring the boundaries between supply chain members and increasing the efficiency of resource exchanges between them (Tsai and Ghoshal, 1998). Furthermore, linkages with suppliers' extended networks (Mu *et al.*, 2008) may provide bridges to sources of unique external information (Tsai and Ghoshal, 1998) that trigger ideas that challenge existing knowledge and understanding. Thus, supplier integration is important to the development of a rich network of diverse knowledge (Jansen *et al.*, 2005) for transforming and exploiting new knowledge.

Hypotheses

Figure 1 provides a summary of the hypotheses that were tested. The first set describes our proposed antecedents to ANT.

Supply chain planning

Supply chain planning provides a foundation for effective supply chain integration and ANT by driving a culture that focusses on future needs (Elbashir *et al.*, 2011), aligning future technology development with corporate strategy. It is important in developing

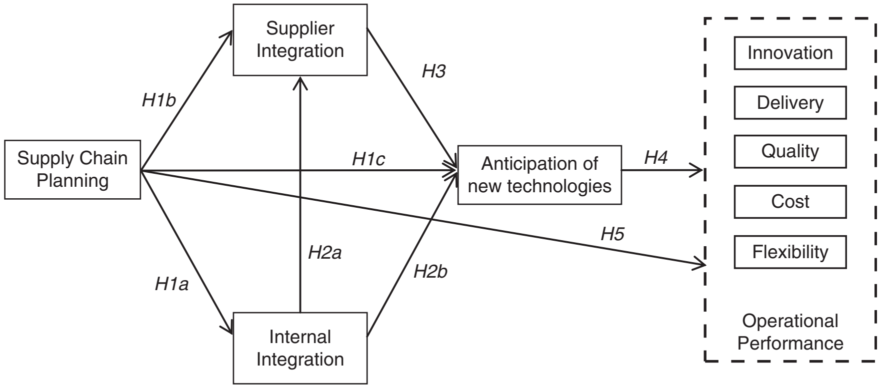


Figure 1.
Proposed model

meaningful supplier integration, providing access to external knowledge from customers, suppliers and their extended supply chain networks and developing integrated internal structures for assimilating external information. Thus, supply chain planning facilitates learning about potential new technologies through the development of networks that facilitate the rapid flow of information:

H1a. Supply chain planning is positively related to internal integration.

H1b. Supply chain planning is positively related to supplier integration.

H1c. Supply chain planning is positively related to ANT.

Internal integration

Internal integration facilitates assimilation by providing a structure for absorbing external knowledge. This is important because firm-specific external knowledge can be difficult for a different organization to relate to. The ability to easily access-related internal expertise facilitates evaluation of the relevance of external technological advances (Cohen and Levinthal, 1990) to future needs. However, internal integration can be challenging, due to what Bowersox *et al.* (1999) described as the "great operating divide" (Bowersox *et al.*, 1999) between the priorities, objectives and terminology of operations-focussed (procurement and manufacturing) and customer-facing (logistics and marketing) activities. The operations-focussed side is driven by the cost to provide goods, while the customer-facing side focusses on the cost to serve customers. Thus, effective internal integration can be a means of competitive differentiation:

H2a. Internal integration is positively related to supplier integration.

H2b. Internal integration is positively related to ANT.

Supplier integration

Supplier relationships can provide novel perspectives about new technologies. Overlap in knowledge with suppliers facilitates detailed, subject-specific interactions (Azadegan, 2011), increasing awareness of supplier capabilities and making information exchanges more efficient. Thus, ANT is enhanced by access to knowledge about new technologies from suppliers and their extended networks:

H3. Supplier integration is positively associated with ANT.

The second set of hypotheses describes the relationship between ANT and performance.

Cost performance

Organizations that are skilled in ANT have the ability to pinpoint technologies that will be needed in their future, while their less skilled competitors may blindly pursue multiple investments and develop capabilities for a variety of new and mostly irrelevant technologies. ANT is an important source of competitive advantage, because it is valuable, rare, imperfectly imitable and non-substitutable (Barney, 2001; Wernerfelt, 1984). Although current technology investments can be easily copied, ANT's focus on developing capabilities for aligning new technologies with future needs provides a combination of hard and soft investments that is difficult to imitate. While other organizations may have a substantial number of false starts down paths to future technology, an organization that has capability in ANT has fewer; thus, ANT is rare. In addition, relationships with suppliers and their extended networks leads to development of a unique domain for the acquisition of external knowledge that is inimitable. ANT is non-substitutable because it must be aligned with an organization's idiosyncratic history, environment and challenges; information from other sources will not be as relevant. Because ANT is valuable, rare, imperfectly imitable and non-substitutable, it is a potent source of competitive advantage. Thus:

H4. ANT is positively associated with performance.

H5. Supply chain planning is positively associated with performance.

Method

Sample

Archival data from the high-performance manufacturing (HPM) project was used. This data were collected from plants in ten countries and three industries. Table I summarizes the sample characteristics.

Table I.
HPM data set by country and industry

Country	Electronics	Machinery	Transportation components	Total
Germany	9	13	19	41
Austria	10	7	4	21
China	21	16	14	51
South Korea	10	10	11	31
Spain	9	9	10	28
USA	9	11	9	29
Finland	14	6	10	30
Italy	10	10	7	27
Japan	10	12	13	35
Sweden	7	10	7	24
Total	109	104	104	317

Note: *n*, number of plants

Instrument

The measurement instrument contained a mix of objective and subjective items on topics related to manufacturing practices, compiled into questionnaires targeted at different respondents. Each item was included on at least three questionnaires, in order to improve validity. Within a given questionnaire, items with the same response choices were intermingled, so that the underlying construct was not readily apparent. The questionnaires were administrated by the plant research coordinator, a plant employee who served as the liaison with the HPM project.

Measurement

The measures are contained in Appendix. Supply chain planning, supplier integration, internal integration and ANT were measured perceptually, using a seven-point Likert scale, ranging from 1 = strongly disagree to 7 = strongly agree. Items relevant to the role that supply chain planning potentially plays in ANT were selected from items originally assigned to HPM measures entitled coordination of plant activities and supply chain planning, which were administered to the inventory manager, three supervisors and the plant superintendent. The items measuring internal integration were originally assigned to HPM measures entitled functional integration and integration between functions, administered to the process engineer, plant manager and plant superintendent in each plant. The ANT measure was developed for the HPM project based on Hayes and Wheelwright's (1984) description and was administered to a process engineer, the plant superintendent and plant manager. The supplier integration measure used items from the HPM project's supplier partnership measure, and it was administered to ten direct labors, the inventory manager and quality manager.

Performance was measured using items from the HPM measure entitled competitive performance, which were completed by the plant manager. He was asked to indicate how the plant compared to its competition in the same industry, on a global basis, using a five-point Likert measure, ranging from 1 = weak, among the worst in the industry to 5 = superior. Specifically, cost was operationalized as unit cost of manufacturing, quality was operationalized as conformance to product specifications, delivery was operationalized as on time delivery performance, flexibility was operationalized as flexibility to change volume and innovation was operationalized as on-time new product launch.

Validity and reliability

Construct validity. Confirmatory factor analysis (CFA) was used to test the reliability and validity of the measures. Items with a factor loading of at least 0.6 were included (Chen and Paulraj, 2004), with a total of five items being excluded during formation of the measures (see Table II). The exclusion of these items did not affect the underlying meaning of the measure; for example, the item excluded from the supplier integration measure focussed on the returns provided to the suppliers, rather than on a core element of supplier integration. The included items had factor loadings between 0.6 and 0.83. All measures exceeded the acceptable minimum for Cronbach's α of 0.60 (Hair *et al.*, 2011), implying that they were internally consistent.

In the original operational performance measure, the item representing cost performance had a factor loading of 0.39, below the criterion of 0.60. This is not surprising, based on the tradeoffs literature (Skinner, 1969); improvements in a dimension of operational performance often only come with increased investment. Thus, cost was extracted from the operational performance measure and retained as an

Construct (α)	Items	Factor loading	α
Anticipation of new technologies	ANT1	0.65	0.806
	ANT2	0.83	
	ANT3	0.63	
	ANT4	0.83	
Internal integration	FI1	0.83	0.908
	FI2	0.74	
	FI3	Excluded (0.54)	
	FI4	Excluded (0.53)	
	FI5	0.85	
	FI6	0.76	
	FI7	Excluded (0.48)	
	FI8	0.73	
	FI9	0.83	
Supply chain planning	SCP1	0.60	0.739
	SCP2	Excluded (0.54)	
	SCP3	0.62	
	SCP4	0.72	
	SCP5	0.63	
Supplier integration	SPT1	0.71	0.800
	SPT2	Excluded (0.47)	
	SPT3	0.77	
	SPT4	0.79	
	SPT5	0.61	
Operational performance	OP1	Extracted (0.39)	0.605
	OP2	0.62	
	OP3	0.67	
	OP4	0.63	
	OP5	0.54	

Table II.
Confirmatory factor analysis and Cronbach's α

independent, single item measure. The final operational performance measure was a formative measure that included quality, delivery, flexibility and innovation performance. Accordingly, *H4* and *H5* were modified to incorporate both endogenous variables, as follows:

H4a. ANT is positively related to operational performance (quality, delivery, flexibility and innovativeness).

H4b. ANT is positively related to cost performance.

H5a. Supply chain planning is positively related to operational performance (quality, delivery, flexibility and innovativeness).

H5b. Supply chain planning is positively related to cost performance.

Convergent validity. Convergent validity was verified by examining the item factor loadings (Koufteros, 1999). Items with factor loadings less than 0.60 were deleted. Table II shows the factor loadings for the retained items.

Discriminant validity. Discriminant validity was evaluated in two ways: the difference in χ^2 (Bagozzi and Yi, 1988) and average variance extracted (AVE) (Fornell and Larcker, 1981). Table III contains the χ^2 values for the constrained and unconstrained models.

Construct pairs	Unconstrained χ^2	df	Constrained χ^2	df	χ^2 difference
Anticipation of new technologies					
Internal integration	50.376	34	151.319	35	100.943*
Supply chain planning	37.098	19	112.227	20	75.129*
Supplier integration	26.104	19	221.885	20	195.781*
Operational performance	48.639	19	215.171	20	166.532*
Supply chain planning					
Internal integration	46.791	33	148.632	34	101.841*
Supplier integration	31.287	19	196.159	20	164.872*
Operational performance	49.936	19	208.230	20	158.294*
Supplier integration					
Internal integration	46.791	33	148.632	34	101.841*
Operational performance	48.186	19	307.712	20	259.526*
Internal integration					
Operational performance	72.129	34	249.519	35	177.390*

Note: $^*p < 0.000$

Table III. Test of χ^2 difference

All differences in χ^2 between the models were significantly different, providing evidence of discriminant validity. Table IV contains a summary of the AVE analysis. Four of the constructs had an AVE above the criterion of 0.5, while supply chain planning had an AVE of 0.46. This measure was retained because it was very close to 0.5 and because its composite reliability and convergent validity provided further evidence of discriminant validity.

Composite reliability. Table IV contains the composite reliability values for the measures. There is no general agreement on an acceptable level (Koufteros, 1999), but values over 0.60 are considered desirable (Bagozzi and Yi, 1988). The composite reliability for each of the measures was over 0.7.

Analysis

The model was assessed using CFA (Chen and Paulraj, 2004). Its adequacy and adjustment were assessed using adjusted goodness of fit, standardized RMR and RMEA as standalone indices, normed fit index, incremental fit index, relative fit index, comparative fit index and Tucker-Lewis coefficient as incremental indices and PNFI, Akaike's information criterion and CAIC for the default, saturated and independence models as indices of parsimonious fit. The proposed relationships were simultaneously verified using structural equation modeling (SEM), allowing analysis of the direct and indirect relationships between the variables.

Constructs	AVE	Composite reliability
Anticipation of new technology	0.56	0.834
Supply chain planning	0.46	0.768
Supplier integration	0.70	0.903
Internal integration	0.74	0.944
Operational performance	0.55	0.788

Table IV. Discriminant validity

Results

Table V presents the fit indices for the measurement model. All of the values were acceptable, suggesting that the proposed model is acceptable. The means, standard deviations and correlation coefficients between the exogenous variables are contained in Table VI, which indicates that there is a significant positive relationship between all exogenous variables.

Figure 2 contains the results of the analysis of the proposed path model, and Table VII contains the goodness of fit indices. All were acceptable, indicating that the proposed path model is a good fit to the data. Table VIII presents the estimated coefficients and their statistical significance. Table IX contains the results of the SEM analysis.

The first set of hypotheses focussed on the antecedents to ANT. The coefficients for the paths from supply chain planning to both internal and supplier integration were

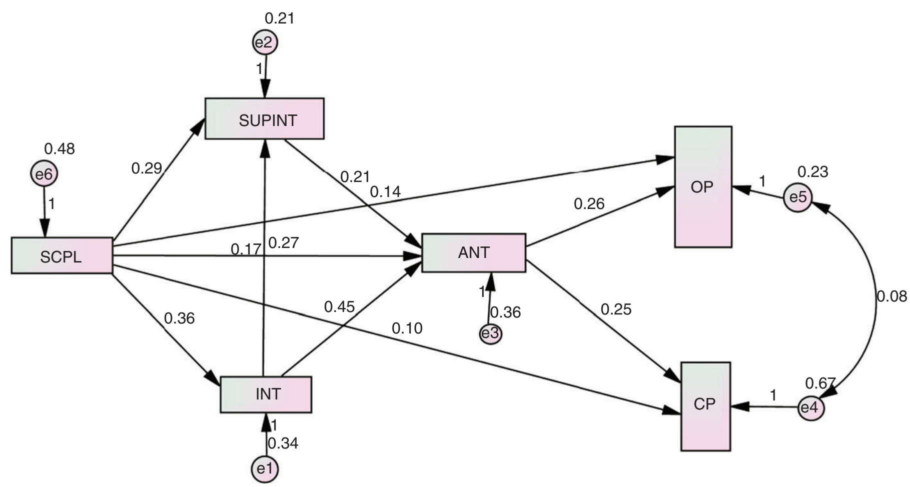
Table V. Fit indices for the measurement model

Index	Value		Criterion
Standalone indices			
χ^2	224.610		
Degrees of freedom (df)	197		
Probability level	0.086		
Goodness of fit (GFI)	0.941		>0.9
Adjusted goodness of fit (AGFI)	0.924		>0.9
Standardized RMR	0.027		Close to 0
RMSEA	0.021		<0.05
Incremental indices			
Normed fit index (NFI)	0.927		>0.9
Incremental fit index (IFI)	0.990		>0.9
Relative fit index (RFI)	0.915		>0.9
Comparative fit index (CFI)	0.990		>0.9
Tucker-Lewis coefficient (TLI)	0.989		>0.9
Indices of parsimonious fit			
PNFI	0.791		>0.5
Akaike's information criterion (AIC)	*AIC*	*CAIC*	
Default model	336.610	603.109	Smallest value must be the proposed
Saturated model	506.000	1,710.002	
Independence model	3,127.231	3,231.927	

Table VI. Descriptive statistics and Pearson correlation coefficients

	n	Mean	SD	Internal integration	Supplier integration	Anticipation of new technologies	Operational performance
Supply chain planning	317	4.9203	0.69070	0.391**	0.452**	0.466**	0.349**
Internal integration	317	5.3173	0.63906		0.352**	0.531**	0.362**
Supplier integration	317	5.2541	0.53161			0.393**	0.228**
Anticipation of new technologies	317	5.1698	0.75648				0.449**
Operational performance	317	3.8347	0.56100				

Note: $^{**}p<0.000$



Notes: SCPL, supply chain planning; SUINT, supplier integration; INT, internal integration; ANT, anticipation of new technology; OP, operational performance (quality, delivery, flexibility and innovation); CP, cost performance

Figure 2.
SEM results

Index	Value		Criterion
χ^2	6.025		
Degrees of freedom (df)	4		
Probability level	0.098		
Goodness of fit (GFI)	0.994		> 0.9
Adjusted goodness of fit (AGFI)	0.967		> 0.9
Standardized RMR	0.009		Close to 0
RMSEA	0.040		< 0.05
Incremental indices			
Normed fit index (NFI)	0.985		> 0.9
Incremental fit index (IFI)	0.995		> 0.9
Relative fit index (RFI)	0.945		> 0.9
Comparative fit index (CFI)	0.995		> 0.9
Tucker-Lewis coefficient (TLI)	0.981		> 0.9
Indices of parsimonious fit			
PNFI	0.263		> 0.5
Akaike's information criterion	*AIC*	*CAIC*	Smallest value must be the proposed
Default model	40.025	120.926	
Saturated model	42.000	141.937	
Independence model	425.992	454.545	

Table VII.
Path analysis fit indices

positive and statistically significant, supporting *H1a* and *H1b*. Organizations with stronger supply chain planning also had stronger internal integration and ANT. Similarly, *H2a* and *H2b* were supported. This indicates that supplier integration and ANT were stronger in the presence of internal integration. Supplier integration had supply chain planning and internal integration as its antecedents. The coefficient for *H3* was positive and statistically significant, thus, supplier integration is related to

Table VIII.
Summary of the SEM test for the model

Hypothesis	Proposed Path	Coefficient	*p*
H1a	Supply chain planning → internal integration	0.362	0.001
H1b	Supply chain planning → supplier Integration	0.286	0.001
H1c	Supply chain planning → anticipation of new technologies	0.275	0.001
H2a	Internal integration → supplier integration	0.172	0.001
H2b	Internal integration → anticipation of new technologies	0.452	0.001
H3	Supplier integration → anticipation of new technologies	0.207	0.004
H4a	Anticipation of new technologies → operational performance	0.262	0.001
H4b	Anticipation of new technologies → cost performance	0.251	0.001
H5a	Supply chain planning → operational performance	0.140	0.001
H5b	Supply chain planning → cost performance	0.103	0.171

Table IX.
Direct and indirect effects (coefficients)

	Direct	Indirect	Total
Effect of supply chain planning			
Supplier integration	0.286	0.062	0.348
Internal integration	0.362	–	0.362
Anticipation of new technologies	0.140	0.164	0.304
Operational performance	0.103 (ns)	0.134	0.237
Cost performance	0.100	0.128	0.228
Effect of supplier integration			
Anticipation of new technologies	0.207	–	0.207
Operational performance	–	0.054	0.054
Cost performance	–	0.052	0.052
Effect of internal integration			
Supplier integration	0.172	–	0.172
Anticipation of new technologies	0.452	0.035	0.487
Operational performance	–	0.127	0.127
Cost performance	–	0.122	0.122
Effect of anticipation of new technologies			
Operational performance	0.262	–	0.262
Cost performance	0.251	–	0.251

ANT. Combined, the results of the tests of *H1-H3* indicate that supply chain planning, internal integration and supplier integration are all antecedents of ANT.

The second set of hypothesis tests focussed on competitive performance. The coefficients for *H4a* and *H4b* were both statistically significant and positive, indicating that ANT was positively related to both operational performance and cost performance. The significant coefficient for *H5a* shows that supply chain planning is related to operational performance. The coefficient for *H5b* was not statistically significant, thus, there was not a direct relationship between supply chain planning and cost performance.

Table IX indicates that there were a number of significant indirect effects. The total effect of supply chain planning was strongest for its relationship with ANT (0.348). Similarly, the strongest total effects of supplier integration (0.207) and internal integration (0.487) were with ANT. Although supply chain planning was not directly related to cost performance, it was indirectly related through its relationship to ANT. This is consistent with the notion that supply chain planning lays for foundation for supply chain integration, which enhances an organization's ability to anticipate new technologies.

Discussion

This research examined the antecedents to ANT, as well as its relationship to operational and cost performance. It found that supply chain planning, internal integration and supplier integration were all associated with ANT, and that it was associated with both operational and cost performance. Furthermore, supply chain planning, internal integration and supplier integration were indirectly related to operational and cost performance, through ANT. The strongest total relationship was between internal integration and ANT. We propose that this is because an organization that has its own house in order internally has a structure for assimilating and transforming external knowledge, which provides important inputs about technology decisions for future generations of products. The total effect of supply chain planning on ANT was the next strongest. While this was partly due to the total effect of internal integration on ANT, it nonetheless demonstrates the importance of supply chain planning on ANT. Thus, through the direct and indirect effects found, this study provides compelling evidence for the importance of supply chain management in supporting ANT.

This research makes several contributions to the literature. First, it provides a reliable and valid measure of ANT. Although this construct was introduced by Hayes and Wheelwright (1984), who discussed its importance, having a reliable and valid measure of ANT provides a foundation for researchers to continue to learn more about this construct. Using CFA, we established the reliability and construct, convergent, discriminant and composite validity of this measure, showing that our measure of ANT is appropriate for future empirical research.

Second, this research provides insights into its infrastructure and effects, by testing ANT in a model that included antecedents and performance measures. We found that organizations that were stronger in ANT had better operations and cost performance. This is consistent with the predictions of Hayes and Wheelwright (1984), proving empirical support for their conceptual description of this construct and its expected effects.

Third, and perhaps most interesting, is that we found that elements of supply chain management were antecedents to ANT. In this sense, we move beyond the conceptual work of Hayes and Wheelwright (1984), who focussed primarily on the expected performance effects of ANT. Although they viewed ANT as a characteristic of world class manufacturers, they put less emphasis on the infrastructure that fosters its development. We found that supply chain planning, supplier integration and internal integration were positively related to ANT; thus, organizations that have stronger supply chain planning, supplier integration and internal integration also had higher levels of ANT. We built upon social capital theory to consider how suppliers' ties with their external networks of customers and suppliers provide access to external knowledge about new technologies and future customer needs that might not otherwise be available. This puts ANT in a different light, placing it in the realm of supply chain management research, as well as operations strategy research.

Fourth, we positioned ANT in the theoretical literature on absorptive capacity, examining Hayes and Wheelwright's (1984) experience-based insights through the lens of well established theory. Understanding the role of supply chain management is important in this positioning, since it provides a means of enhancing the absorptive capacity that underlies ANT. We propose that focussing on technologies that may be important in the future provides the impetus for environmental scanning to accelerate knowledge acquisition, and suppliers and their external networks are critical sources of external knowledge. Internal integration provides a structure for analyzing, processing, interpreting and developing an understanding of external knowledge, supporting assimilation. Similarly, supply chain planning and internal integration are important in transformation and exploitation of external knowledge about technology that may be important in the future. This positioning in the theoretical literature is important in understanding ANT and providing a foundation for future research on this important construct. Although we described ANT in the context of absorptive capacity, we did not test any absorptive capacity constructs; this is a fruitful area for future research. Thus, by positioning ANT in the theoretical literature, we hope that we have revitalized the discussion of a well-respected established construct that has not benefitted from prior empirical testing.

This research is relevant in today's dynamic global environment, despite being based on a construct that was proposed almost 30 years ago. In the face of a rapidly changing competitive environment, ANT has the potential to be a powerful competitive weapon to give an organization an edge over its competitors which, like Company A, remain focussed on using today's technologies to address today's problems. Although this may be a very effective short-term strategy, it does not position an organization well for dealing with a changing environment. Furthermore, today's global extended supply chains provide a potential treasure trove of knowledge about technology for organizations that recognize and capitalize on it. Testing the role of ANT in a dynamic environment provides an important opportunity for future research.

In addition to its contribution to the theoretical literature, this research has strong managerial implications. It is based on Hayes and Wheelwright's (1984) work with companies and managers, so its roots are inherently practical. By shedding new light on an old construct, we hope to provide a reminder of the importance of focussing on future customer needs and the technology and capabilities to support them, in order to develop them in advance of actual need. Second, this research shows that Hayes and Wheelwright's (1984) practical prescriptions are valid. The association between ANT and operational performance shows the importance of a technology strategy that looks to the future, as well as the present. Although it is important to stay current with competitors in terms of technology, this is the road to competitive parity, as illustrated Company A. Because state-of-the-art process and manufacturing technology is available to any organization that has the resources to invest in it, only keeping up with technology does not provide a source of competitive differentiation. Thus, to achieve a competitive advantage, future, as well as current, technology needs should be considered, as illustrated by Company B.

Third, we highlight the importance of supply chain management practices in fostering ANT. By viewing supply chain partners and their partners as a source of important technology knowledge and developing a means for systematically capturing this knowledge, processing it and capitalizing on it, ANT is enhanced. This also supports the notion of world class manufacturing as building upon linkages between many diverse practices. Relationships with suppliers are enhanced by strong internal integration, providing the ability to use knowledge acquired externally. When the operations-facing and customer-facing sides of an organization speak the same language and work together to collaboratively achieve goals, supplier integration is facilitated. A strong internal structure facilitates development of understanding so that external knowledge can be applied to the organization's unique problems and improve its operational performance.

Future directions and limitations

While Hayes and Wheelwright's (1984) work is rich with managerial implications, it has not, for the most part, been subject to empirical scrutiny. ANT is one of their three "acid tests" for being a world class (stage 4) manufacturer. The other two acid tests are the extent to which an organization develops its own proprietary equipment and the extent of integration between structural and infrastructural decisions. There are many important research questions based on the three acid tests, including whether they are, indeed, the key differentiators between the best manufacturers in the world and the others. Do they interact with each other and, if so, how? Is there a common infrastructure that supports their development? By developing a reliable and valid measure for one of Hayes and Wheelwright's (1984) acid tests, we have contributed to this discussion, but this is only the beginning.

On a broader level, ANT is an element of world class manufacturing, but there are numerous important research questions about its other elements, their relationship with each other and their relationship with performance. In particular, it is likely that there are other important antecedents to ANT, beyond the supply chain management factors examined in this research. ANT may also interact with other elements of world class manufacturing in its influence on performance.

Part of what makes research on world class manufacturing so challenging is that its components may be implemented differently in different national cultures. For example, the long-term orientation (Hofstede, 2001) of a national culture may be important in its orientation toward ANT. Examining the relationship between long-term orientation and ANT may be insightful. Further, it is important to consider potential substitutes for long-term orientation; in a national culture with a shorter-term focus, are there alternative ways to lay a foundation for ANT?

As with all empirical research, there are a number of potential limitations that should be articulated. The use of an existing database like the HPM database can be restrictive in terms of the research questions that can be investigated. In this study, however, the HPM database included measures relevant to ANT and supply chain integration. Thus, the content of the database led to few restrictions on the research ideas and questions proposed.

Focussing on the plant as the unit of analysis may have limited conclusions regarding performance and the impact of ANT. This leads to several opportunities for future research. First, it is important to consider the corporate perspective of ANT, which may provide valuable insights into how future products, markets and strategic needs are envisioned, as well as how that vision is communicated to the plant level. Second, consideration of supply chain integration that includes the perspectives of customers and suppliers, as well as the focal organization, will enrich future studies of the role that supply chain management plays in ANT.

This study focussed only on suppliers as a supply chain source of new technology knowledge. However, customers may also be a potent source of new technology knowledge. Like suppliers, customers have their own extended networks of customers and suppliers that can provide access to different sources of knowledge about technologies that align with anticipated future needs. Future studies of ANT should include customer integration, as well as supplier integration.

Anticipation of technologies is an important strategic construct that has not benefitted from prior empirical study. This study lays the foundation for future research on this topic through the establishment of a reliable and valid measure and examination of its supply chain management antecedents. There are many opportunities for further development and understanding of this construct through future research.

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Appendix. Measures

Please indicate the extent to which you agree with each of the following statements (1 = strongly disagree, 7 = strongly agree)	
Internal integration	
II1	The functions in our plant are well integrated
II2	Problems between functions are solved easily, in this plant
II3	Functional coordination works well in our plant (Excluded).
II4	Our business strategy is implemented without conflicts between functions (Excluded)
II5	The functions in our plant work well together
II6	The functions in our plant cooperate to solve conflicts between them, when they arise
II7	The marketing and finance areas know a great deal about manufacturing (Excluded)
II8	Our plant's functions coordinate their activities
II9	Our plant's functions work interactively with each other
Supply chain planning	
SCP1	Our corporation implements ordering and stock management policies, on a global measure, in order to coordinate distribution
SCP2	Our corporation performs aggregate planning for plants, according to our global distribution needs (Excluded)
SCP3	Our corporation transfers technological innovations and know-how between plants
SCP4	We actively plan supply chain activities
SCP5	We monitor the performance of members of our supply chains, in order to adjust supply chain plans
Anticipation of new technologies	
ANT1	We pursue long-range programs, in order to acquire manufacturing capabilities in advance of our needs
ANT2	We make an effort to anticipate the potential of new manufacturing practices and technologies
ANT3	Our plant stays on the leading edge of new technology in our industry
ANT4	We are constantly thinking of the next generation of manufacturing technology
Supplier integration	
SPT1	We maintain cooperative relationships with our suppliers
SPT2	We provide a fair return to our suppliers (Excluded)
SPT3	We help our suppliers to improve their quality
SPT4	We maintain close communications with suppliers about quality considerations and design changes
SPT5	Our key suppliers provide input into our product development projects
Please indicate the performance of your plant, compared with its global competitors (1 = weak, among the worst in the industry, 5 = superior)	
Operational performance	
OP1	Unit cost of manufacturing (Extracted)
OP2	Conformance to product specifications
OP3	On time delivery performance
OP4	Flexibility to change volume
OP5	On time new product launch

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